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Satellite Networks Workshop
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ASSESSMENT OF EMERGING NETWORKS TO SUPPORT FUTURE NASA SPACE OPERATIONS

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Badri Younes
CLASS Project Manager
Code 450/NASA GSFC
Susan Chang,
Ted Berman,
Mark Burns,
Richard LaFontaine,
Robert Lease
Stanford Telecom

Introduction

- New types of global commercial satellite systems are currently under development and expected to start providing service in 1998
  - Global communication coverage
  - Mobile communication capability
  - High speed networking
- NASA GSFC is investigating the feasibility of using emerging commercial satellite systems to support NASA LEO missions
  - Reduce mission cost
  - Enhance or maintain level of service provided by TDRSS and GN

NASA Study

- Examines technical and operational issues related to supporting a NASA LEO satellite with commercial satellite systems
- Four commercial satellite systems are addressed in this presentation
  - Mobile Satellite Service (MSS): IRIDIUM, ICO (1st gen)
  - Fixed Satellite Service (FSS): Spaceway, Teledesic

Evaluation Approach

- Communications Coverage: Geometric coverage time minus system acquisition and service acquisition time.
  - Accounts for time required for handoff
  - Accounts for dropped calls due to handoff failure
- NASA user terminal assessment including spacecraft G/T, EIRP and operational constraints relating to system acquisition, service acquisition and handoff
- Regulatory assessment

Assumptions

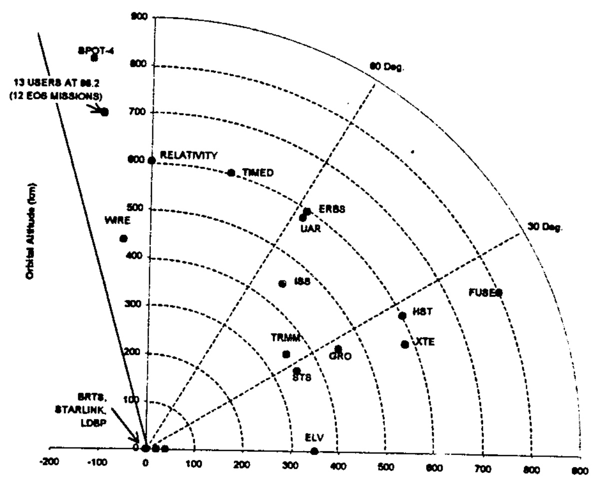
- **No modifications will be made to commercial satellite systems to support NASA missions.**
  - NASA LEO satellite will emulate a ground-based user
- **User spacecraft tracking will not be performed by the commercial satellite systems.**
  - Future NASA missions will incorporate on-board GPS equipment
- **All evaluations of the commercial satellite systems are based on public information obtained from FCC filings**

NASA LEO Missions Overview

- **NASA missions operate in a number of different orbits that depend on the mission type**
  - Launch vehicles at approximate altitudes of up to 350 km
  - Suborbital missions at altitudes less than 40 km
  - Manned space flight at altitudes of 300 - 600 km altitude and inclinations of 28°- 57°
  - Astrophysics missions at altitudes of 400 - 600 km altitude and inclinations of 23°- 35°
  - Earth science missions at altitudes of 350 - 1,350 km and inclinations of 35°- 99°
- **Considered missions scheduled through 2014**
- **Data requirements range from 1 kbps to 600 Mbps**
  - Telemetry and Command: 1 kbps to 2 Mbps
  - Payload data: 1 kbps to 600 Mbps

NASA LEO Missions Overview

Orbital Characteristics



Commercial Satellite Systems

Summary

System	Orbit Type/ Service type	BER	Service Frequency (MHz)		Service Data Rate (kbps)		ISL Frequency (GHz)	Orbit Parameters		
			Forward •	Return	Forward	Return		Satellites	Altitude (km)	Inclination
Iridium[1]	LEO MSS	10^{-3}	1616-1626.5	1616-1626.5	2.4	2.4	23.18-23.38	66	780	86.4°
ICO	MEO MSS	10^{-5}	2,170–2,200	1,985-2,015	38.4	38.4	N/A	10-12	10,355	45°
Teledesic[1]	LEO FSS	10^{-8}	17.8-18.6 and 18.8-19.3	28.6-29.1 and 27.6-28.4	n*16 (n= 1,...,128)	n*16 (n= 1,...,128)	65-71	288	1350	84.7°
Spaceway[1]	GEO FSS	10^{-10}	17.7-20.2	27.5-30.0	92,000	384-6,000	22.55-23.55 32-33 54.25-58.20 59-64	20	35,786	0°

Notes:
1. Systems use intersatellite links and onboard data processing.

Simulation Assumptions

- Geometrical coverage determined through Communications Analysis Graphical Environment (CAGE) simulation
  - Ten day orbit simulation
  - Commercial satellite user antenna beam modeled as a single conic
- Communications coverage determined through CAGE simulation
  - 30 random user satellite orbit periods
  - User satellite is positioned at a randomly selected accession angle prior to each simulation pass
  - User antenna beam modeled at sub-beam level
  - System acquisition time based on IS95 specification (16.3 sec)
  - Service acquisition time based on IS95 specification (20.0 sec)
  - Handoff time based on existing ground based cellular system performance (12 s)

Simulation Results

- Emerging commercial satellite systems are designed for users at or near ground level. Communications coverage at LEO altitudes is constrained.
  - Reduced communications coverage exist at LEO altitude due to the conic shape of the radiating antenna
  - Beam-to-beam handoff for a LEO spacecraft will experience a higher call drop probability than a terrestrial user due to user spacecraft velocity (12 km/sec)
- None of the evaluated systems is capable of supporting the real time communications coverage requirements of manned space flight missions and launch vehicles
- IRIDIUM and Teledesic provide the least communications coverage
  - Orbits similar to NASA LEO spacecraft
  - Less than 1% communications coverage for user altitudes > 500 km
- ICO provides higher communications service duration and data throughput
  - Service availability 20% - 40% for user altitudes > 500 km
- Spaceway (GEO) provides highest communications service duration and data throughput
  - Service availability is greater then 35% for user altitudes > 500 km
  - NASA LEO satellite must support beam-to-beam handoff (not available on FSS)

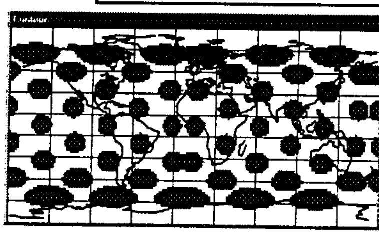
Communications Coverage - IRIDIUM

IRIDIUM Service Availability Analysis Results [1,2]

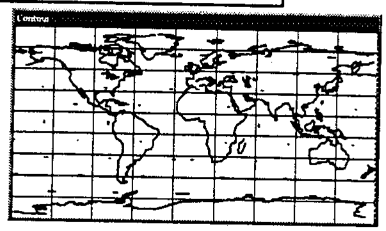
Parameter	CASE 1 300 km, 28.5 deg	CASE 2 500 km, 28.5 deg	CASE 3 700 km, 28.5 deg	CASE 4 500 km, 57.0 deg	CASE 5 700 km, 98.2 deg
FOV Coverage (%)	30.4	6.5	0.3	9.3	0.7
Service Availability (%)	6.0	0.5	-	-	-
Service Availability/orbit (minutes)	5.4	0.5	-	-	-
Average Service Duration (minutes)	0.9	0.4	-	-	-
Average Null Duration (minutes)	14.5	83.6	-	-	-
Maximum Null Duration	90.5	94.6	-	-	-
Contacts per User Period (avg)	5.9	1.1	-	-	-
Call Dropping Probability (%)	63.2	66.7	-	-	-

NOTES:

1. The estimated mean sub-beam FOV time (sec) for Cases 1 through 5 as follows: 1) 21.9 seconds, 2) 11.4 seconds, 3) 3.0 seconds, 4) 11.4 seconds, 5) 3.0 seconds.
2. The estimated mean sub-beam overlap time (sec) for Cases 1 through 5 as follows: 1) 5.9 seconds, 2) 3.1 seconds, 3) 0.8 seconds, 4) 3.1 seconds, 5) 0.8 seconds.
3. 48 spot beams per IRIDIUM satellite



IRIDIUM FOV COVERAGE AT 300 Km ALTITUDE



IRIDIUM FOV COVERAGE AT 700 Km ALTITUDE

Communications Coverage - ICO

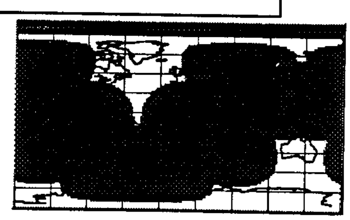
ICO Service Availability Analysis Results [1,2]

Parameter	CASE 1 300 km, 28.5 deg	CASE 2 500 km, 28.5 deg	CASE 3 700 km, 28.5 deg	CASE 4 500 km, 57.0 deg	CASE 5 700 km, 98.2 deg
FOV coverage (%)	99.0	96.1	93.2	88.6	76.9
Service availability (%)	53.8	49.3	44.9	67.5	22.0
Service availability/orbit (minutes)	46.7	46.6	44.3	63.8	21.7
Average service duration (minutes)	3.4	3.2	3.0	4.6	1.0
Average null duration (minutes)	2.9	3.3	3.7	2.2	3.7
Maximum null duration	20.5	20.6	20.7	20.8	38.1
Contacts per user period (avg)	14.4	14.6	14.7	14.0	21.0
Call dropping probability (%)	49.6	48.5	47.5	36.7	67.7

NOTES:

1. The estimated mean sub-beam FOV time (sec) for Cases 1 through 5 as follows: 1) 63.7 seconds, 2) 57.8 seconds, 3) 53.0 seconds, 4) 57.8 seconds, 5) 53.2 seconds.
2. The estimated mean sub-beam overlap time (sec) for Cases 1 through 5 as follows: 1) 17.2 seconds, 2) 15.6 seconds, 3) 14.4 seconds, 4) 15.6 seconds, 5) 14.4 seconds.
3. 163 spot beams per ICO satellite

ICO FOV COVERAGE AT 300 km



ICO FOV COVERAGE AT 700 km

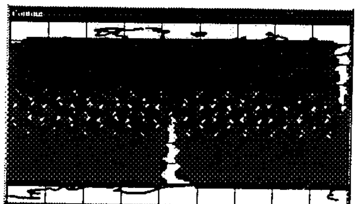
Communications Coverage - Teledesic

Teledesic Service Availability Analysis Results[1,2]

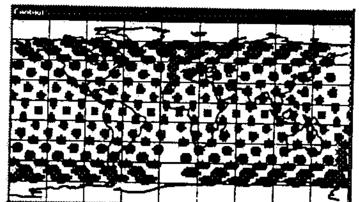
Parameter	CASE 1 300 km, 28.5 deg	CASE 2 500 km, 28.5 deg	CASE 3 700 km, 28.5 deg	CASE 4 500 km, 57.0 deg	CASE 5 700 km, 98.2 deg
FOV coverage (%)	97.8	66.4	34.6	75.5	50.5
Service Availability (%)	3.3	1.3	0.4	1.2	0.1
Service Availability/orbit (minutes)	3.0	1.2	0.4	1.1	0.1
Average Service Duration (minutes)	0.7	0.5	0.3	0.4	0.3
Average Null Duration (minutes)	48.0	72.3	96.5	50.9	98.8
Maximum Null Duration	90.5	94.6	98.8	94.6	98.8
Contacts per User Period (avg)	1.9	1.3	1.0	1.8	1.0
Call Dropping Probability (%)	64.9	66.2	74.1	70.3	74.6

NOTES:

1. The estimated mean sub-beam FOV time (sec) for Cases 1 through 5 as follows: 1) 6.7 seconds, 2) 5.2 seconds, 3) 3.8 seconds, 4) 5.2 seconds, 5) 3.8 seconds.
2. The estimated mean sub-beam overlap time (sec) for Cases 1 through 5 as follows: 1) 1.8 seconds, 2) 1.4 seconds, 3) 1.0 seconds, 4) 1.4 seconds, 5) 1.0 seconds.
3. 64 spot beams per Teledesic satellite



TELEDESIC FOV COVERAGE AT 300 KM ALTITUDE



TELEDESIC FOV COVERAGE AT 700 KM ALTITUDE

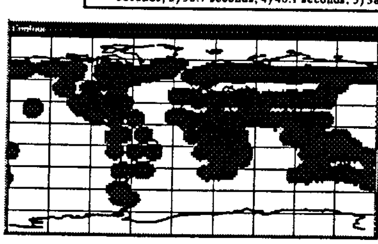
Communications Coverage - Spaceway

Spaceway Service Availability Analysis Results[1,2]

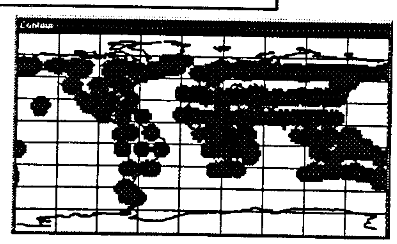
Parameter	CASE 1 300 km, 28.5 deg	CASE 2 500 km, 28.5 deg	CASE 3 700 km, 28.5 deg	CASE 4 500 km, 57.0 deg	CASE 5 700 km, 98.2 deg
FOV coverage (%)	53.4	51.6	50.1	47.8	35.7
Service availability (%)	53.0	51.4	47.2	46.9	35.9
Service availability/orbit (minutes)	48.0	48.6	46.6	44.4	35.5
Average service duration (minutes)	6.3	6.2	5.6	5.5	4.2
Average null duration (minutes)	5.6	5.9	6.3	6.1	7.5
Maximum null duration	41.5	43.7	47.7	47.1	55.9
Contacts per user period (avg.)	7.6	7.8	8.3	8.2	8.4
Call dropping probability (%)	21.9	23.2	26.3	29.6	44.1

NOTES:

1. The estimated mean sub-beam FOV time (sec) for Cases 1 through 5 as follows: 1) 154.0 seconds, 2) 149.0 seconds, 3) 144.0 seconds, 4) 149.0 seconds, 5) 144.0 seconds.
2. The estimated mean sub-beam overlap time (sec) for Cases 1 through 5 as follows: 1) 41.6 seconds, 2) 40.1 seconds, 3) 38.7 seconds, 4) 40.1 seconds, 5) 38.7 seconds.



Spaceway FOV Coverage at 300 km altitude



Spaceway FOV Coverage at 700 km altitude

User Terminal Assessment

- NASA LEO spacecraft will require a smaller terminal than TDRSS, for MSS, systems due to MSS LEO and MEO constellations
- FSS systems do not provide NASA LEO spacecraft any substantial terminal size advantage over TDRSS
  - GEO systems are designed to support ground users and require a high G/T and EIRP to support high burst rate TDMA
- Large number of satellites in commercial constellations will increase NASA spacecraft memory and processing burden
  - Need to determine when and where data can be transmitted
- Additional processing burden for NASA satellites
  - Doppler correction, power management, burst transmission management (TDMA), and beam-to-beam handoff

Regulatory Considerations

- Services provided by commercial satellite systems are governed by International Radio Regulations and U.S. statutes
- Definitions of MSS and FSS do not provide for space-to-space links required for NASA support
- NASA service support scenarios would require regulatory amendments
  - Feasibility studies
  - Marketing efforts
  - 4 to 14 year estimated implementation time