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# ***Overview of LEO Satellite Systems***

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# Overview

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- Characteristics of LEO Systems
- Emergence of LEO Technology
- Classification of LEOs
- LEO Systems
- Iridium
- Government Involvement
- Conclusion



# ***Characteristics of LEO Systems***

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- “Anytime, Anywhere”
- Blends cellular and satellite technologies
  - Satellite
  - Terrestrial
  - Gateways
- 500 - 2000 km orbit
  - Below Van Allen Belts
- Fiber-like propagation delay
- Voice and data capabilities
- Hand-held multi-mode phones



# ***Emergence of LEO Technology***

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- Lower propagation delay in LEO vs GEO
  - toll quality voice circuits now possible
  - IP over satellite
- Use of Ka frequency band vs C and Ku
  - smaller antennas
- Advances in satellite technology
  - ACTS, MILSTAR
  - inter-satellite links (ISL)
  - on-board processing
  - switching, routing, store-and-forward
  - improvements in satellite manufacturing process



# ***Emergence of LEO Technology***

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- Spot beam frequency reuse
- Lower launch costs
  - Multiple satellites per launch
  - New launch sites in China and Russia
- Need for global wireless services
  - voice
  - data
- Bandwidth demand
  - data applications
- Vocoder technology
  - toll quality voice at 2400 bps



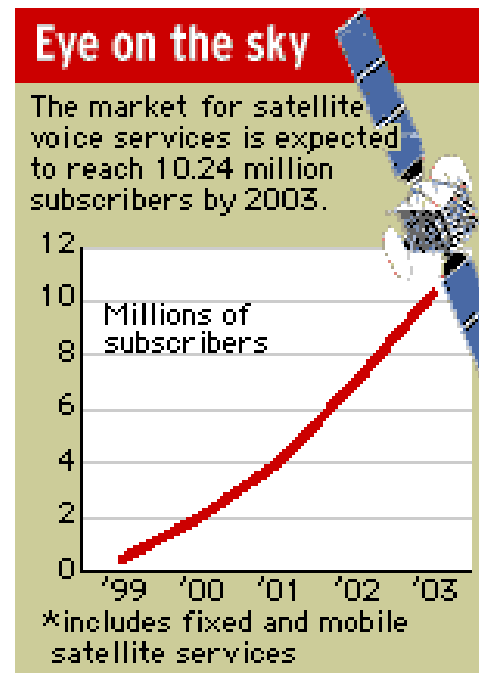
# ***LEO versus GEO***

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- Less propagation delay for LEOs
- More LEOs required for global coverage
- Single LEO failure will not result in lost communication
- Less exposure to Van Allen Belt radiation
- Inter-satellite links versus bent-pipe
- Jitter
- Ka band
  - Rain attenuation



# LEO Subscriber Growth



Source: Dataquest



# ***Classes of LEOs***

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- Little LEOs
  - Non-voice services
  - Orbcomm
  - LEO One
  - Final Analysis
- Big LEOs
  - Voice plus limited data services
  - Iridium
  - Globalstar
  - Constellation Communications
- Broadband LEOs
  - High-speed data plus voice
  - Teledesic
  - SkyBridge





# Little LEOs

System	Orbcomm	LEO One	Final Analysis
<b>Company</b>	Orbcomm, Orbital Sciences	LEO One	Final Analysis, General Dynamics Info Systems
<b>Service Types</b>	messaging, paging, e-mail	messaging, paging, e-mail	messaging, e-mail, file transfer
<b>Voice (kbps)</b>	-----	-----	-----
<b>Data Rate</b>	2.4 kbps uplink 4.8 kbps downlink	2.4-9.6 kbps uplink 24 kbps downlink	TBD
<b>Orbit Altitude (km)</b>	825	950	1000
<b>No. of Satellites</b>	48	48	38
<b>No. of Orbit Planes</b>	3	8	7
<b>Earth Stations</b>	10	20	7
<b>Mobile Uplink</b>	148-150 MHz	148-150 MHz	VHF/UHF
<b>Mobile Downlink</b>	137-138 MHz, 400 MHz	137-138 MHz	137-138 MHz
<b>Feeder Uplink</b>	148-150 MHz	148-150.5 MHz	VHF/UHF
<b>Feeder Downlink</b>	137-138 MHz, 400 MHz	400.15-401 MHz	VHF/UHF
<b>ISL</b>	No	No	No
<b>Service Date</b>	1996	2002	2001



# Big LEOs

System	Iridium	Globalstar	Constellation Communications
<b>Company</b>	Motorola	Loral, Alcatel, Qualcomm	Orbital Sciences, Bell Atlantic, Raytheon
<b>Service Types</b>	voice, data, fax, paging, messaging	voice, data, fax, paging, messaging	voice, data, fax
<b>Voice (kbps)</b>	2.4	adaptive 2.4 / 4.8 / 9.6	2.4
<b>Data (kbps)</b>	2.4	7.2	28.8
<b>Orbit Altitude (km)</b>	780	1410	2000
<b>Number of Satellites</b>	66	48	46
<b>Orbit Planes</b>	6	8	8
<b>Earth Stations</b>	15 - 20	100 - 210	TBD
<b>Beams / Satellite</b>	48	16	24/32
<b>Footprint Dia. (km)</b>	4700	5850	TBD
<b>Mobile Uplink (MHz)</b>	1616 - 1626.5 (L-band)	1610 - 1626.5 (L-band)	2483.5 - 2500 (S-band)
<b>Mobile Downlink (MHz)</b>	1616 - 1626.5 (L-band)	2483.5 - 2500.0 (S-band)	1610 - 1626.5 (L-band)
<b>Feeder Uplink (GHz)</b>	27.5 - 30.0 (Ka-band)	5.091 - 5.250 (C-band)	5.091 - 5.250 (C-band)
<b>Feeder Downlink (GHz)</b>	18.8 - 20.2 (Ka-band)	6.875 - 7.055 (C-band)	6.924 - 7.075 (C-band)
<b>ISL</b>	Yes (4)	No	No
<b>Service Date</b>	1998	2000	2001

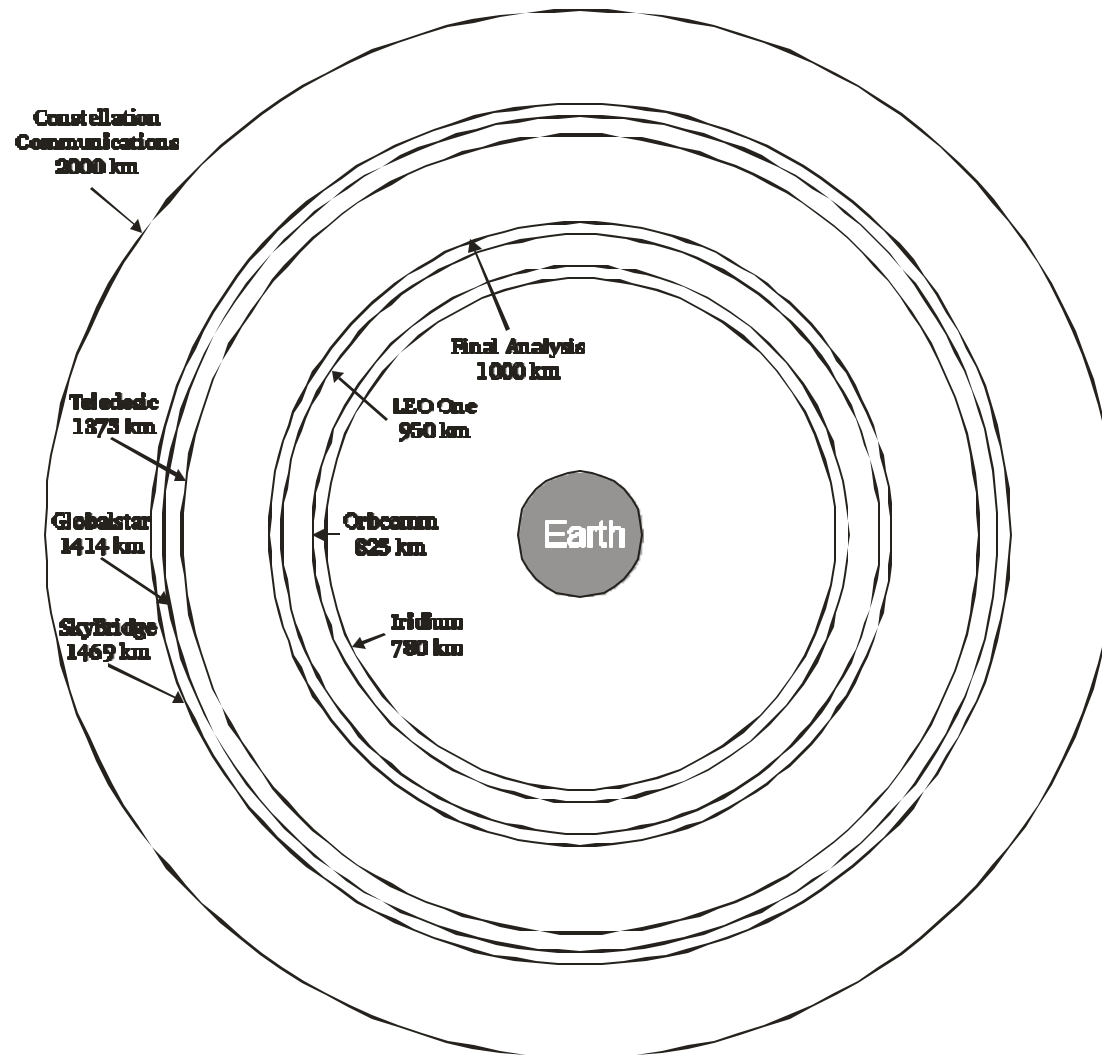


# Broadband LEOs

System	SkyBridge	Teledesic
Company	Alcatel, Loral	Motorola, Boeing, Matra Marconi, Gates, McCaw
Service Types	internet access, voice, data, video, videoconferencing	internet access, voice, data, video, videoconferencing
Voice (kbps)	TBD	16
Data (kbps)	2,000 uplink 20,000 downlink	2,000 uplink 64,000 downlink
Orbit Altitude (km)	1469	1375
Number of Satellites	80	288
Number of Orbit Planes	2	12
Earth Stations	200	TBD
Beams / Satellite	~50	64
Footprint Diameter(km)	3000	1412
Feeder Uplink (MHz)	Ku-band	28,600 - 29,100 (Ka-band)
Feeder Downlink (MHz)	Ku-band	18,800 - 19,300 (Ka-band)
ISL	No	Yes (8)
Service Date	2001	2004



# LEO Orbital Altitudes





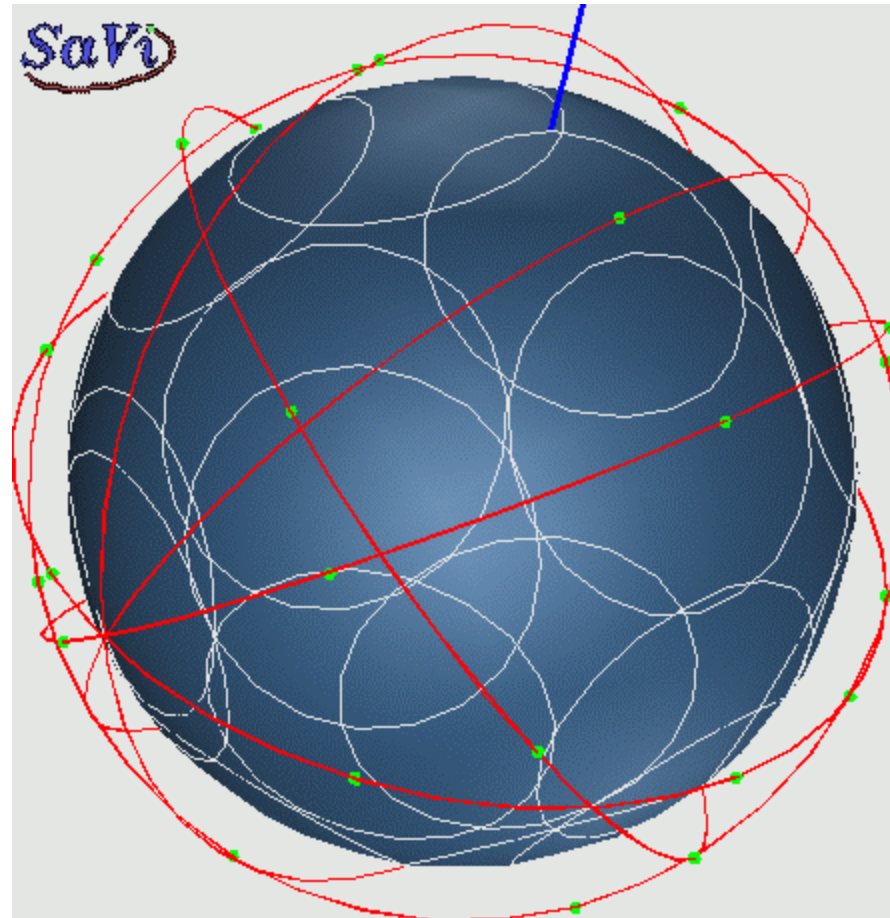
# *Orbcomm*

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- Operational since 1996
- Trailer tracking services for trucking fleets
- Two-way messaging technology being marketed to US government and military
- GPS hand-held satellite communicator integrates Orbcomm technology for worldwide messaging
- Internet capabilities
  - Planned IP messaging gateway for HTTP, XML and UDP messaging functions
  - SMTP/POP3 and X.400 global wireless e-mail



# Orbcomm Constellation





# ***LEO One***

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- Provides near real-time store-and-forward messaging
  - tracking and fleet management
  - monitoring and remote control
  - two-way messaging
  - emergency services
  - transaction processing
- Finished development of satellite antenna system and gateway station



# *Final Analysis*

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- 36 satellites in 6 orbital planes at 51E
  - 2 satellites in 83E plane
- Three ground stations completed
- Terminals
  - Remote Terminal
  - Messaging Terminal
  - File Transfer Terminal
- Services offered
  - real-time
  - near real-time
  - store and forward





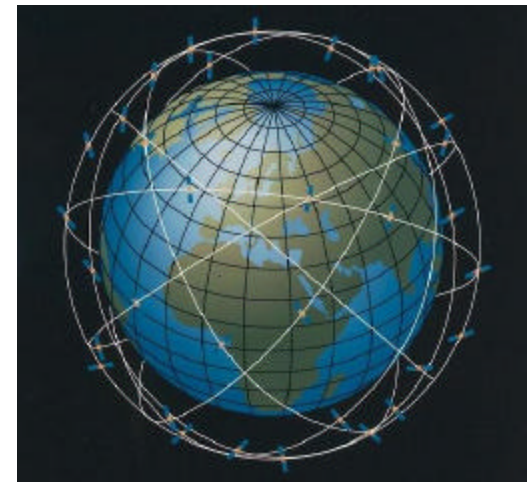
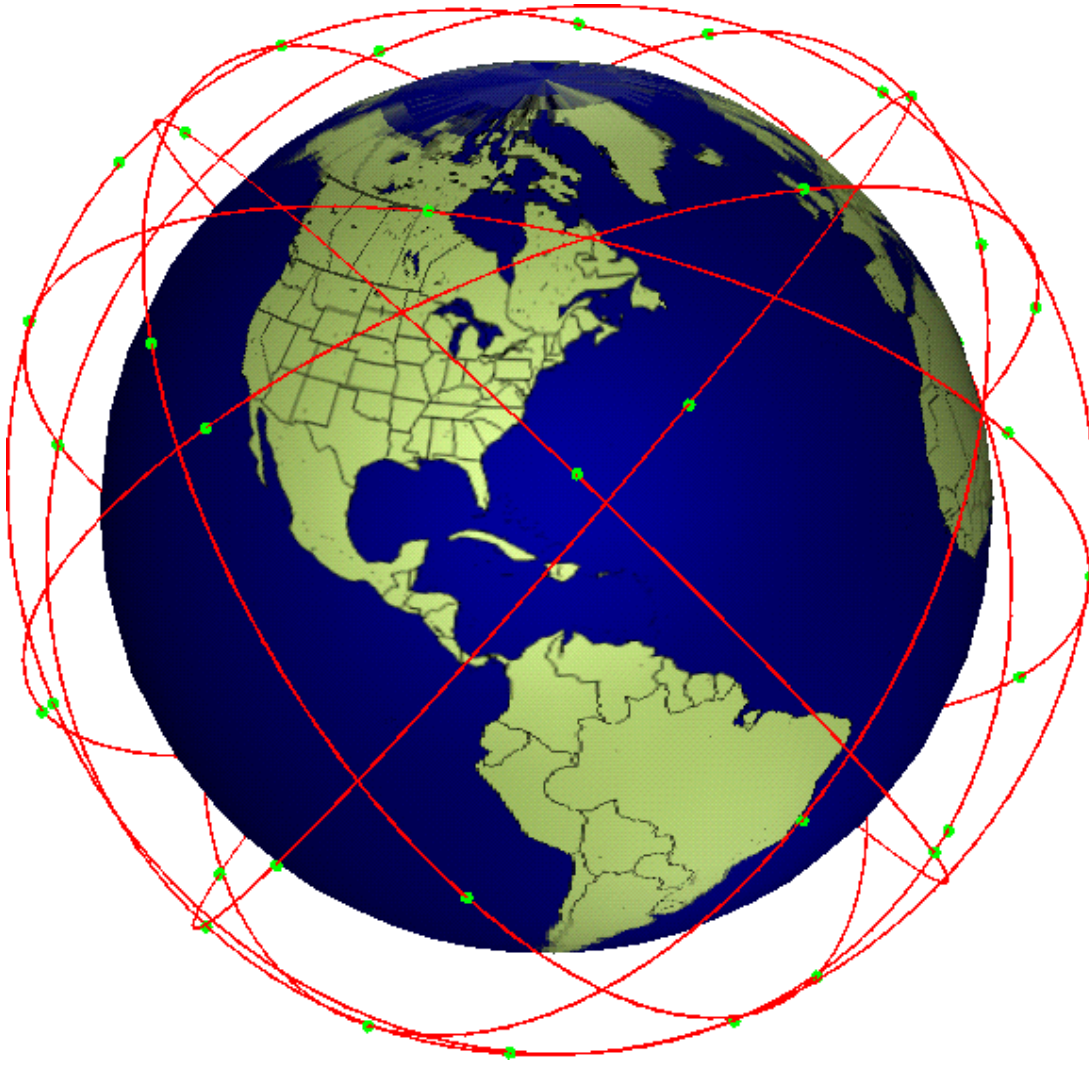
# ***Globalstar***

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- 36 Globalstar satellites in space as of August 17 launch
- Fleet of 48 will be in orbit by December
  - 4 per launch
- Commercial service to start October 10
- Employs bent-pipe vs ISL
  - proven technology
- Coverage concentrated between +/- 70E
- Phone manufacturers
  - Ericsson, Qualcomm and Telital



# Globalstar Constellation





# ***Constellation Communications***

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- Data oriented
- Initial phase will have single equatorial orbit of 11 satellites
  - Coverage between +/- 23 E
  - Service to begin in 2001
- Additional 35 will be deployed
  - Five per orbit in seven circular inclined orbits
  - Global service in 2003



# *Teledesic*

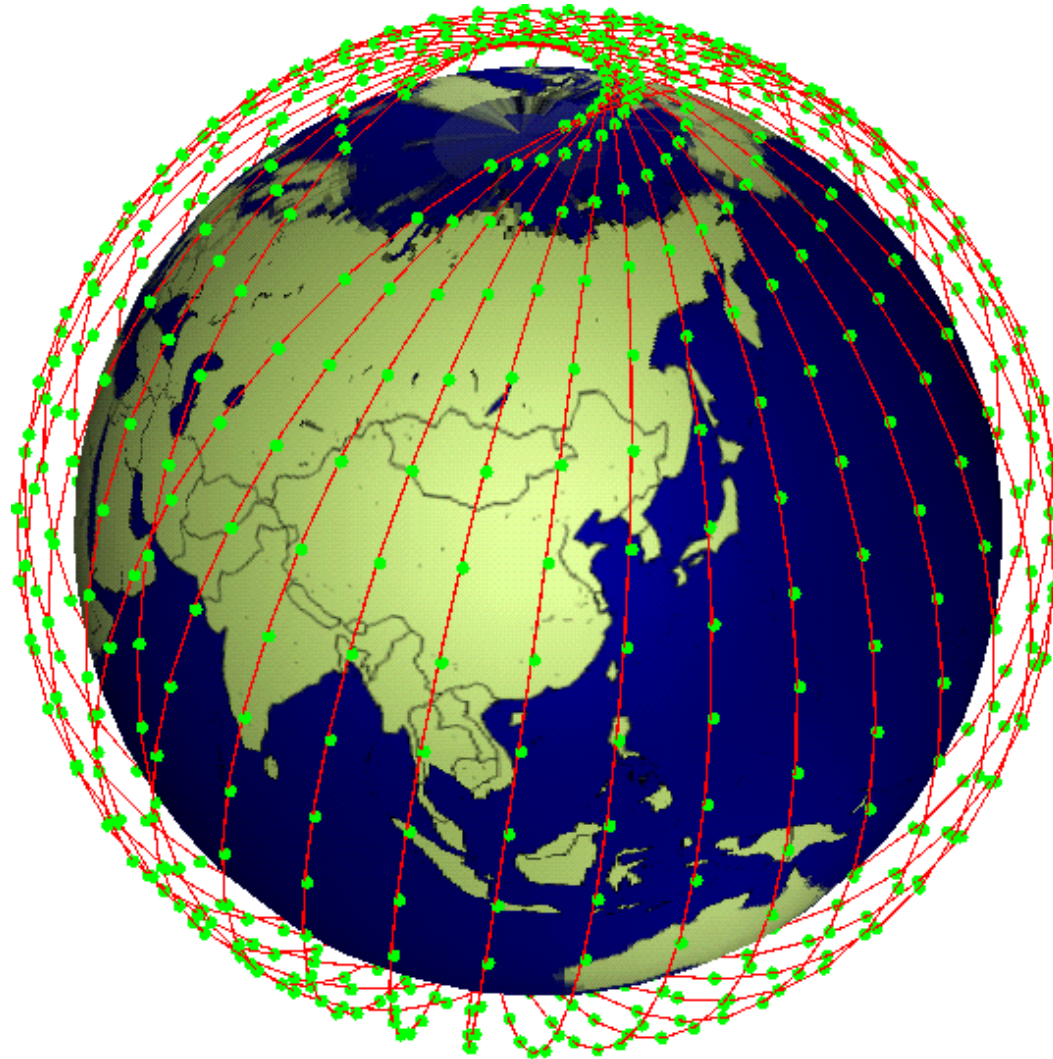
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- Combines efforts with Celestri (1998)
  - Motorola becomes prime Teledesic partner
- “Internet-in-the-sky”
- Portable vs mobile
  - 45 cm antenna
  - directional
- Lockheed Martin launch provider
- Motorola - constellation's system provider



# Teledesic Constellation

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# *SkyBridge*

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- Protects GEO systems in the Ku-band through frequency re-use concept
- Proven technologies reduce cost and overall risks of system
  - gateways use ATM-based interfaces
  - supports Internet protocols
  - "bent-pipe" system
  - terrestrial-based switching
  - Ku-band frequency
    - lower hardware costs due to mature technology
    - less signal attenuation due to rain than Ka frequencies



# *Iridium*

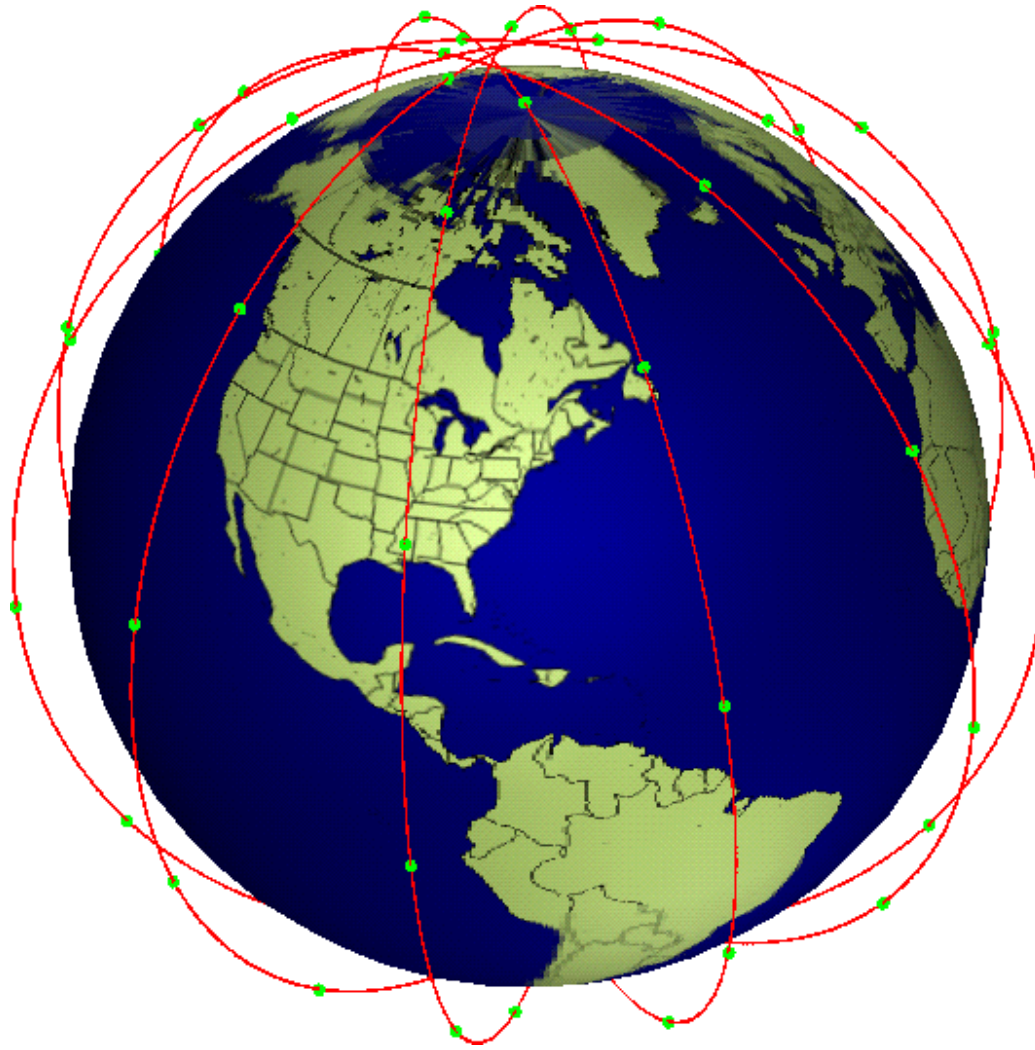
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- Voice network operational since November 98
- On-board processing and ISLs
- Separate voice and data channels
  - 2400 bps voice: low latency
  - 2400 bps data: error-free delivery
  - packet switched
  - data channel expected in 99
- Types of connections
  - Iridium to/from PSTN
  - Iridium to Iridium



# *Iridium Constellation*

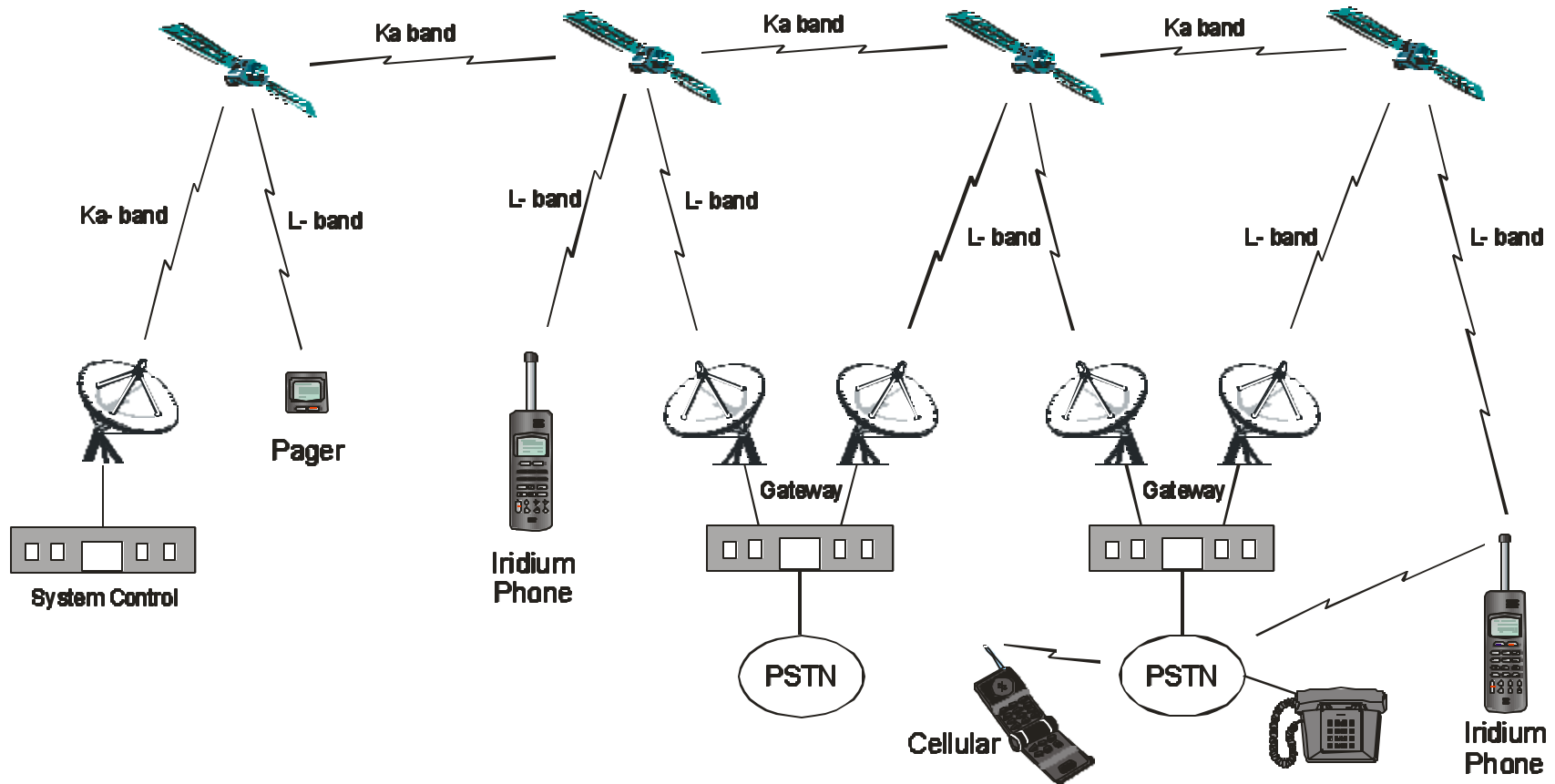
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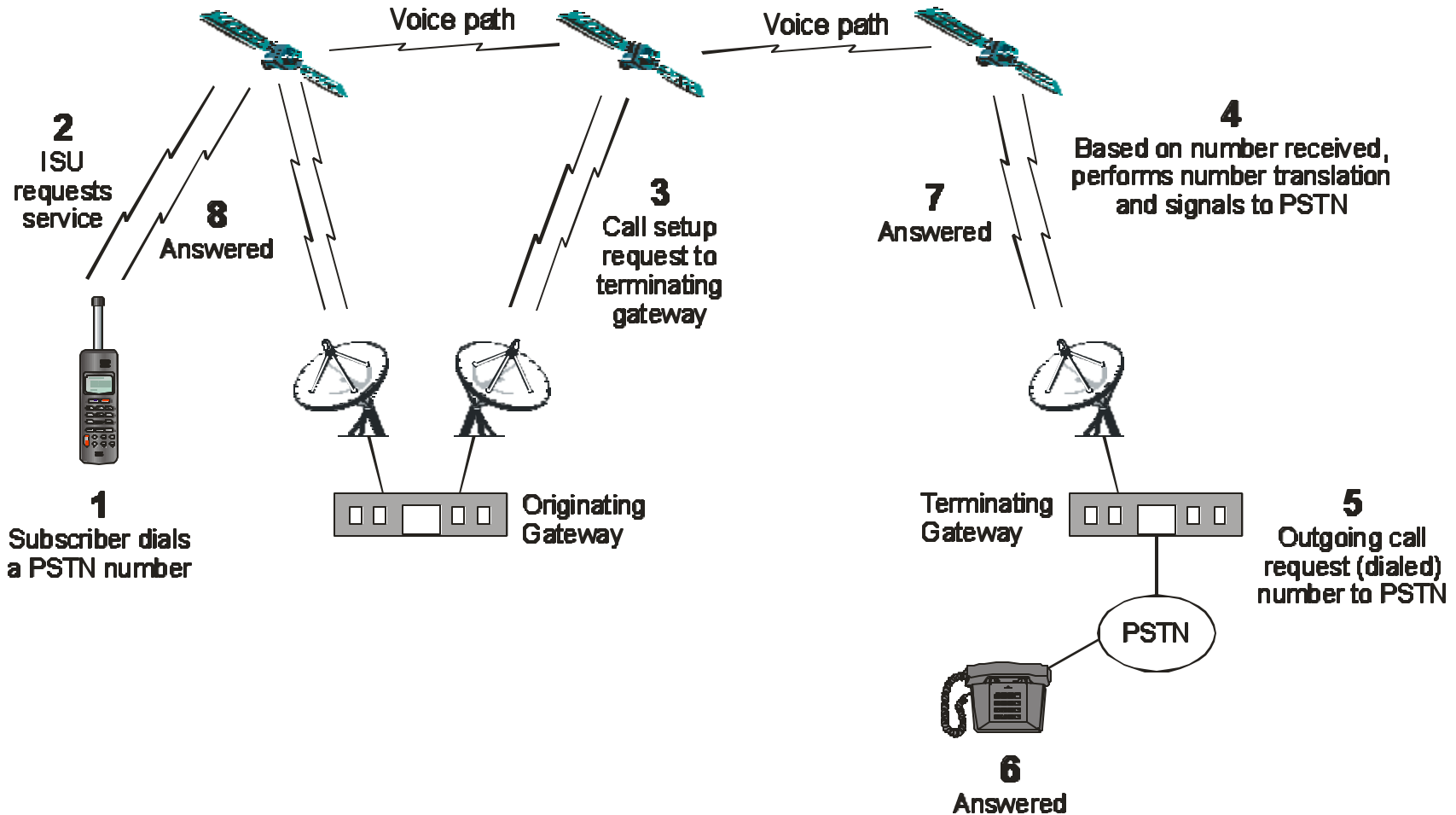


# Iridium System Overview





# Iridium Call Scenario





## ***Iridium in the News***

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- Iridium gets US Military as First Big Customer (1/26/98)
- The World's First Global Satellite Telephone and Paging Company Starts Service (11/1/98)
- Iridium CEO opts to leave (6/14/99)
- Iridium cuts staff, stock suffers (6/14/99)
- Iridium cuts prices to boost subscriber base (6/21/99)
- Motorola calls for help with Iridium (7/14/99)
- Iridium Files Chapter 11 Bankruptcy (8/13/99)



# ***Government Involvement***

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- **Enhanced Mobile Satellite Service (EMSS)**
  - Iridium network
  - 4 DISA contracts (> \$300M)
  - Secure calling via DoD gateway
  - End-to-end security via secure phones
- **Future Narrow Band Digital Terminal (FNBDT)**
  - Government funded / Industry supported
  - Working Group formed to develop secure mode of operation between STU-III and GSM, CDMA and LEO satellite systems such as Iridium and Globalstar



# ***Conclusion***

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- LEO satellites in period of great interest
- Latency eases voice and IP applications
- ISL vs bent-pipe
- Broadband LEOs will provide last mile broadband connectivity gap
- Iridium effects on other LEOs
- Seamless global communications now a reality