Based on MOOS system requirements Nov. 29, 2000

Wireless Communications Requirements - Executive Summary

Process	Ave Data	Norm. Ave Data	Estimated Minutes/Month		Yearly Cost		Cost Ratio
			Iridium	Globalstar	Iridium	Globalstar	
All possible instruments	1.0GB/day	97.00kbps	547117min/mo	783709min/mo	$6,302,972	$8,369,468	0.75:1
Multi-scale Oceanographic	3.3MB/day	0.30kbps	1722min/mo	2467min/mo	$20,021	$25,809	0.78:1
Canyon Processes - normal	257.0kB/day	0.02kbps	135min/mo	194min/mo	$1,737	$2,330	0.75:1
Canyon Processes - event	1.3MB/day	0.12kbps	676min/mo	968min/mo	$7,967	$9,801	0.81:1
Active Mid-ocean Ridge	71.3MB/day	6.60kbps	37520min/mo	53744min/mo	$432,406	$573,449	0.75:1
Benthic Carbon cycles	3.3MB/day	0.31kbps	1736min/mo	2487min/mo	$20,179	$26,018	0.78:1
Standard 1MB/day Baseline 12mos.	1.0MB/day		526min/mo	754min/mo	$6,240	$7,507	0.83:1

without Iridium Linux compression*

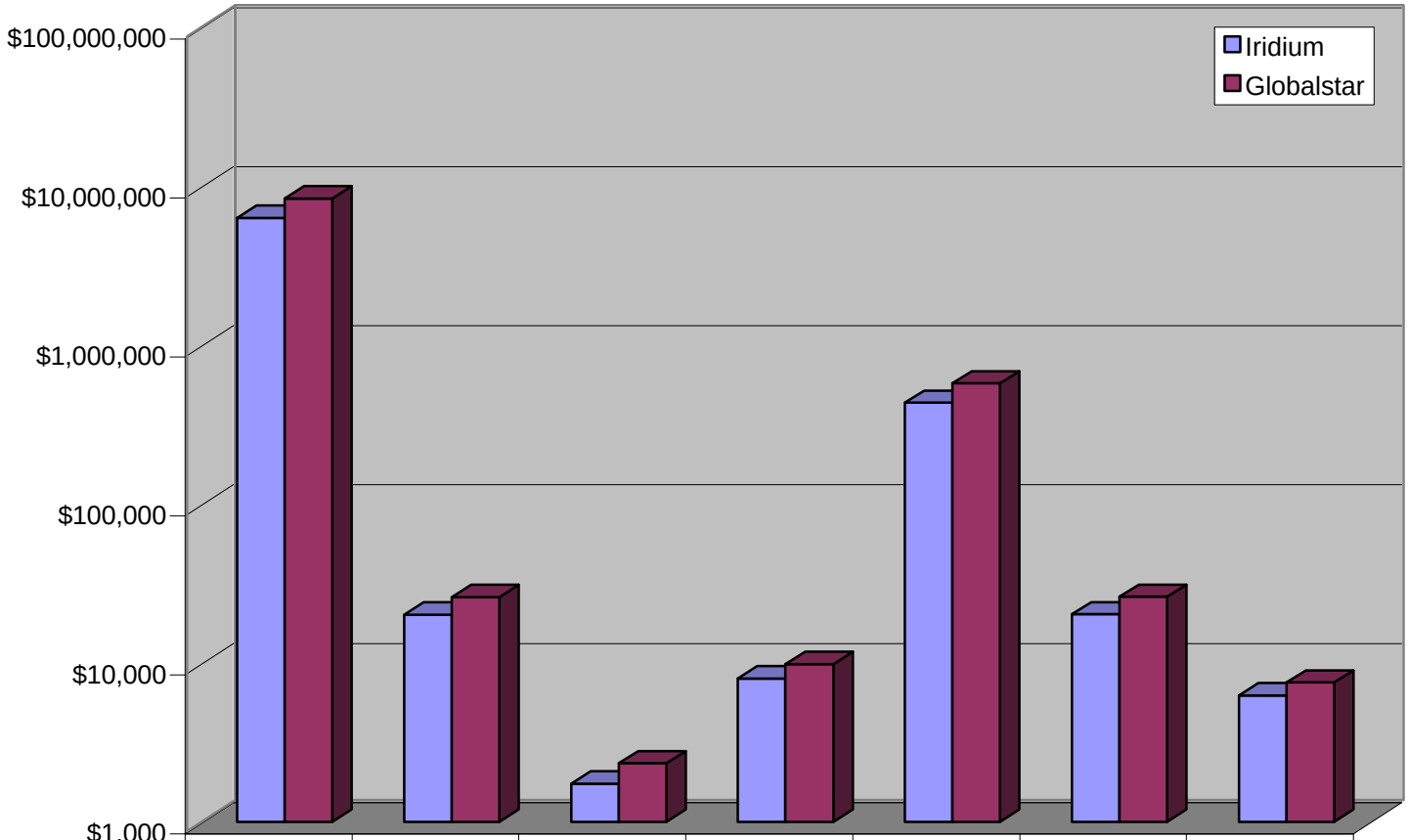
Process	Ave Data	Norm. Ave Data	Estimated Minutes/Month		Yearly Cost		Cost Ratio
			Iridium	Globalstar	Iridium	Globalstar	
All possible instruments	1.0GB/day	97.00kbps	2416435min/mo	783709min/mo	$27,837,513	$8,369,468	3.33:1
Multi-scale Oceanographic	3.3MB/day	0.30kbps	7607min/mo	2467min/mo	$87,813	$25,809	3.40:1
Canyon Processes - normal	257.0kB/day	0.02kbps	597min/mo	194min/mo	$7,058	$2,330	3.03:1
Canyon Processes - event	1.3MB/day	0.12kbps	2986min/mo	968min/mo	$34,575	$9,801	3.53:1
Active Mid-ocean Ridge	71.3MB/day	6.60kbps	165712min/mo	53744min/mo	$1,909,178	$573,449	3.33:1
Benthic Carbon cycles	3.3MB/day	0.31kbps	7668min/mo	2487min/mo	$88,509	$26,018	3.40:1
Standard 1MB/day Baseline 12mos.	1.0MB/day		2323min/mo	754min/mo	$26,946	$7,507	3.59:1

*Currently Iridium compression software is Windows based (Brand Communications Ltd.)

Points of interest

1. Iridium backed by US Government
1.a. Iridium certified by government bureaucracy as solid thru 2010
2 Iridium's satellite-satellite comms allow low-operating costs due to lack of recurring costs for multiple ground stations
3. Iridium launched 5 LEO satellites in February
3.a. Iridium has 66 satellites in it's primary communication network
3.b. Iridium has 7 spare satellites in orbit
4. Iridium launching 2 more satellites in June
5. Globalstar requires multiple land stations due to bent-pipe architecture
5.a. Current business model only supports limited land base and 200nm ocean boundry
5.b. Never completed ground stations in Africa
6. Globalstar lost 12 satellites in rocket crash
6.a. No spare satellites available
7. Globalstar requires a 2-element antenna
8. Rumors indicate Iridium compression allowing 24kbps in the near future with 56-64kbps in 6-8mos.
8.a. Iridium technology is being actively developed
9. Qualcomm stopped making Globalstar modems in the summer of 2001
9.a. Approx 10's of thousands available
10. Motorola has licensed support of Iridium 9505 unit to General Dynamics
11. Free NAL Iridium data units/satellite time available from Oceans.US
11.a. "free" doesn't cover "telephone" time (unsure of costs in this program)
12. Possible to use Iridium antenna as GPS antenna as well
13. We have a Globalstar modem now.

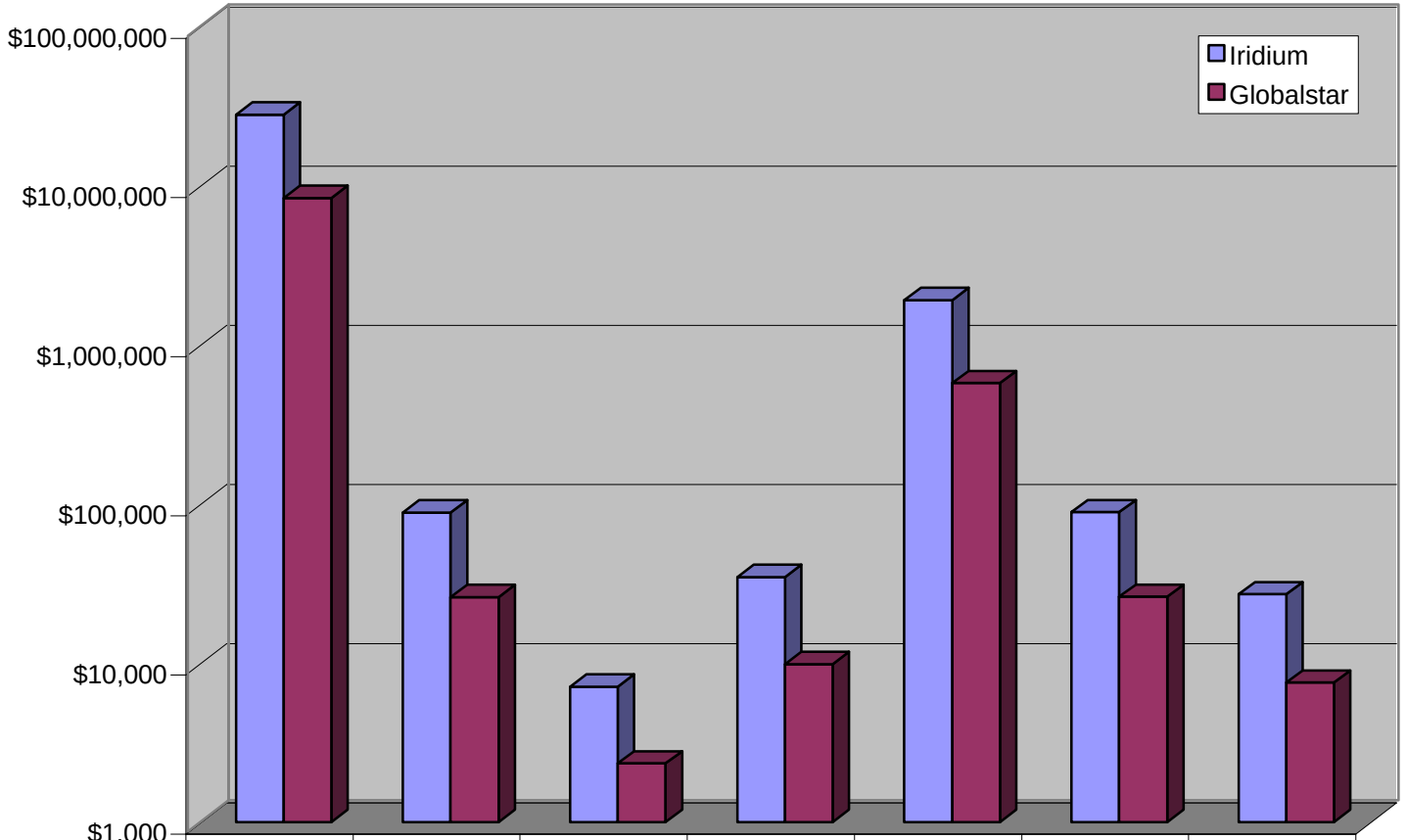
Yearly Satellite Communication Costs - Iridium Gateway (10kbps)



	All possible instruments	Multi-scale Oceanographic	Canyon Processes - normal	Canyon Processes - event	Active Mid-ocean Ridge	Benthic Carbon cycles	Standard 1MB/day Baseline 12mos.
Iridium	$6,302,972	$20,021	$1,737	$7,967	$432,406	$20,179	$6,240
Globalstar	$8,369,468	$25,809	$2,330	$9,801	$573,449	$26,018	$7,507

Process

Yearly Satellite Communications Costs - Iridium Dialup (2.4kbps)



	All possible instruments	Multi-scale Oceanographic	Canyon Processes - normal	Canyon Processes - event	Active Mid-ocean Ridge	Benthic Carbon cycles	Standard 1MB/day Baseline 12mos.
Iridium	$27,837,513	$87,813	$7,058	$34,575	$1,909,178	$88,509	$26,946
Globalstar	$8,369,468	$25,809	$2,330	$9,801	$573,449	$26,018	$7,507

Process

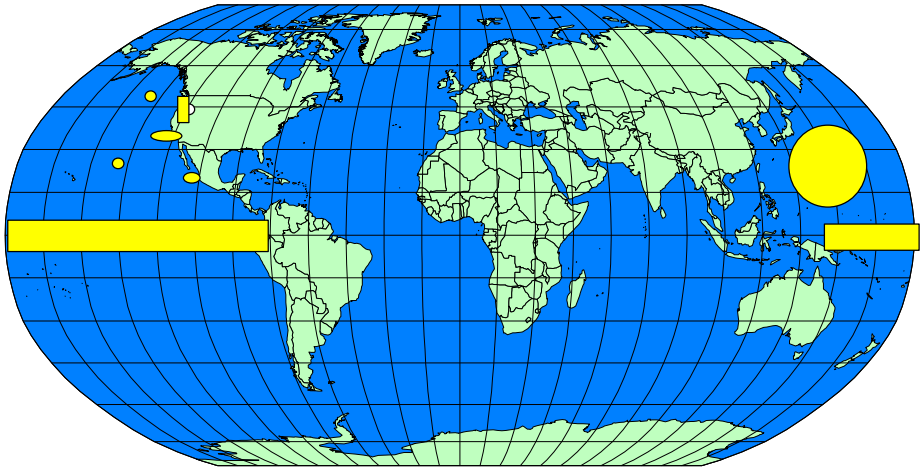
MOOS Deployment locations & wireless comms coverage report

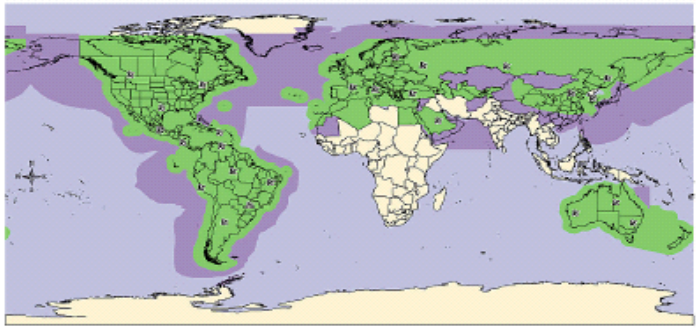
	Satellite						Local RF			
Location	Globalstar	Iridium	Orbcomm	Wavix	GOES	Inmarsat	Freewave	Integra	METEORBURST	RF Industries
· Monterey Bay area and immediately adjacent waters extending out 1000 kilometers (3500m)	yes	yes	yes	yes	yes	yes	some	some	yes	some
· Equatorial pacific	no	yes	yes	yes	some	yes	no	no	no	no
· Northern area of the East Pacific Rise southwest of Mexico's Baja Peninsula	yes	yes	yes	yes	yes	yes	no	no	no	no
· Ocean station "P" at 50N, 145W in the North Pacific (4150m)	yes*	yes	yes	yes	yes	yes	no	no	no	no
· Axial Seamount (1600m)	yes	yes	yes	yes	yes	yes	no	no	yes	no
· Juan De Fuca ridge complex (2500m)	yes	yes	yes	yes	yes	yes	no	no	yes	no
· Gorda ridge (3900m)	yes	yes	yes	yes	yes	yes	no	no	yes	no
· Loihi Seamount, 35 kilometers south east of Hawaii	no	yes	yes	yes	yes	yes	no	no	no	no
· Locations in the western Pacific (5500m)	some*	yes	yes	yes	some	yes	no	no	no	no
· Central pacific gyre area off Monterey Bay (4500m)	yes	yes	yes	yes	yes	yes	no	no	yes	no

*with extended coverage only

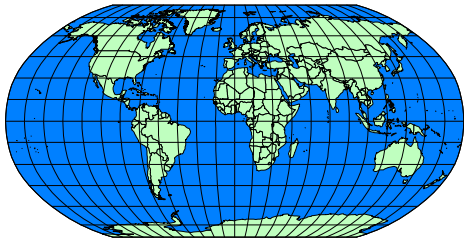
Sattelite Communications Coverage relative to desired deployment locations

Note: Required coverage areas indicated by yellow markers.

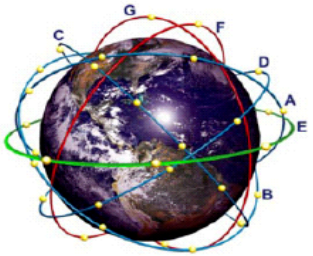




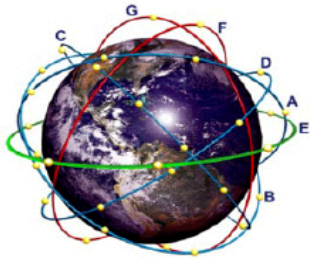
Globalstar coverage map from www.globalstar.com



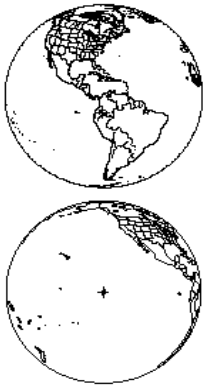
Iridium provides worldwide coverage



inmarsat provides worldwide coverage
(except polar regions)



Orbcomm provides worldwide coverage
(limited over polar regions)



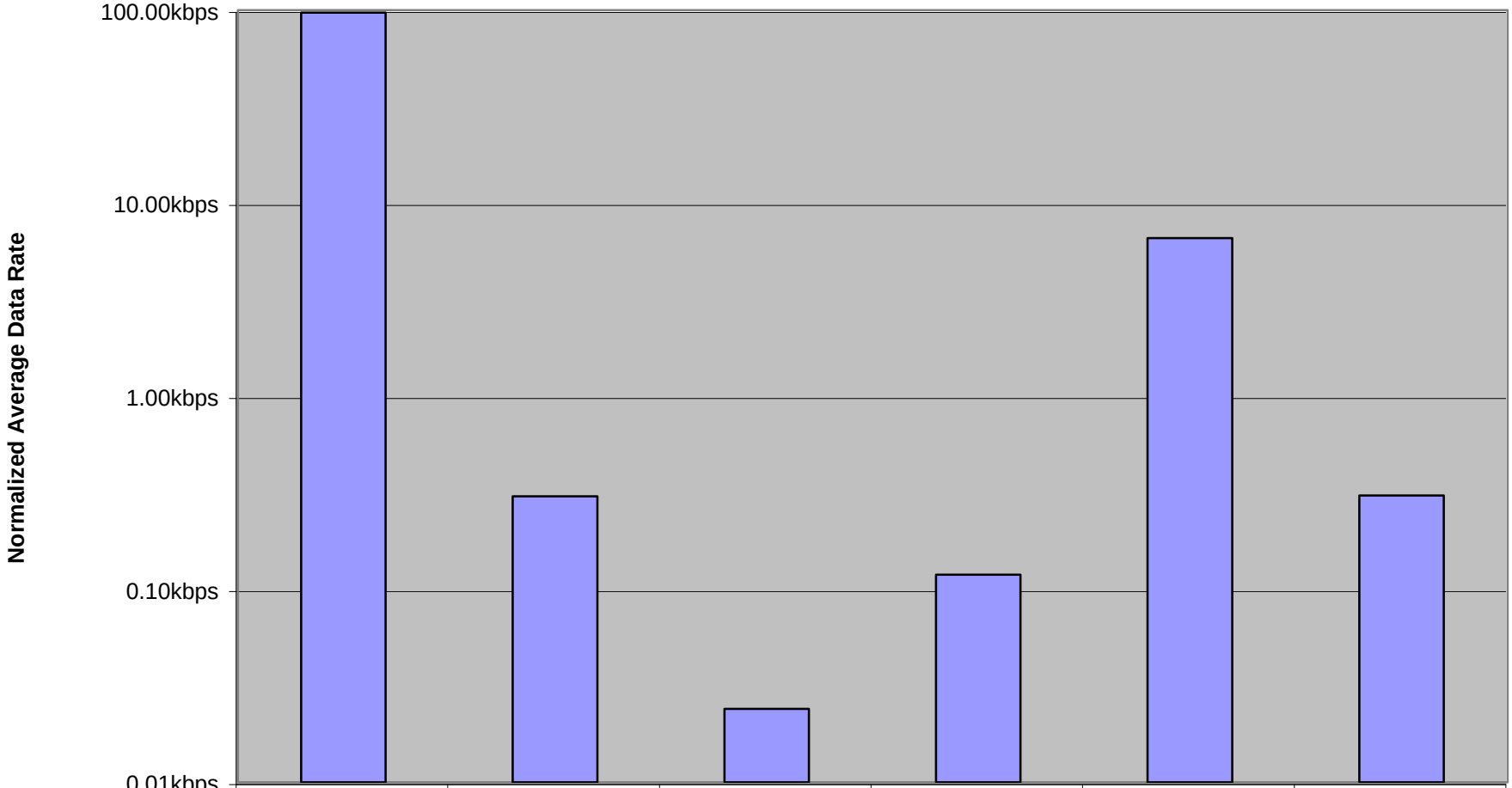
GOES geosync Coverage

Communications Requirements - Details

Comm System	Advertised Bandwidth	Compression Ratio	Range	Frequency Transmit	Frequency Receive	Max xmit Pwr	Link Margin	Interface	Quiescent Power consumption	xmit Power Consumption	Power consumption/bit	Duplex Method	Equipment Price	Price/min	Price/bit	Est. Min/Mo.	Operating Temp	Size	Board or Case	Antenna Height	Antenna Type	Notes
Iridium - Data	2.40kbps	1:1	worldwide	1620MHz	1620MHz		12.5dB	AT Modem	100mA @ 4.4V	6.60W	0.00275J/bit	TDMA/FDMA	$1,200	$0.96	$0.000400		-30c to +60c	38mm x 71mm	Case	7.50"	Bell	5 sats launched in Feb., 2 more launching in June, backed by US Gov., Single land station (open to data tracking by Big Brother), Sat-sat comms, Solid thru 2010, NAL modem lead time = 2-3wks
Globalstar - Data	7.40kbps	1:1	US coastal	1620MHz	2500MHz	26.0dBm		AT Modem	100mA @ 5.6V	4.80W	0.00065J/bit		$750	SEE PRICING	$0.000002		-30c to +60c	15mm x 75mm	Board	2.50"	Bell	No spare satellites available (lost 12 on an aborted launch), dependant on land-based gateways (Pacific/Atlantic?), None in Africa, Availability?, Unit available now
Orbcomm	2.40kbps	1:1	worldwide (polar?)	149MHz	138MHz	37.0dBm		RS-232C		14.40W	0.00600J/bit	SDPSK					-40c to +75c	33mm x 89mm	Case	28.00"	Omnidirectional Dipole	
Freewave	115.00kbps	1:1	32km	915MHz	915MHz	29.8dBm	23.4dB	AT Modem		7.80W	0.00007J/bit	GFSK (Gausian Frequency Shift Keying)		$0.00	$0.000000		-40c to +75c	60mm x 78mm	Case	12.25"	Omnidirectional Dipole	
RF Industries	9.60kbps	1:1	local	500MHz	500MHz	37.0dBm		RS-232C		18.75W	0.00195J/bit	GFSK (Gausian Frequency Shift Keying)		$0.00	$0.000000		-30c to +60c		Case			
Wavix	0.40kbps	1:1	worldwide	149MHz	400MHz			RS-232C		97.50W	0.24375J/bit						0c to +40c	152mm x 305m	Case	36.00"	Mast	
Integra	19.20kbps	1:1	local																			
Inmarsat-C	0.60kbps	1:1	worldwide - polar	1650MHz	1550MHz	44.0dBm		RS-232C				BPSK	$3,600				-25c to +55c	50mm x 165mm	Case	4.88"'	Mast	
GOES	0.01kbps	1:1	NA & East Pacific			12.0dBm		RS-232C		48.00W	3.69231J/bit						-40c to +50c	38mm x 140mm	Case			
ARGOS	0.00kbps	1:1	worldwide	402MHz	402MHz												-30c to +60c	25mm x 70mm	Case			

Globalstar Pricing	(877) 728-5947	
5 min/mon	$24.95	
+ /min	$1.49	
50 min/mon	$69.95	
+ /min	$1.39	
100 min/mon	$119.95	
+ /min	$1.19	
250 min/mon	$249.95	
+ /min	$0.99	
500 min/mon	$399.95	
+ /min	$0.89	
Iridium Pricing		
Paging - 1 year contract		
Stand alone	$59.95	
Activation	$59.95	
Pagers	$195.00	$375.00
Data		
activation	$50.00	
sim	$50.00	
monthly	$14.95	
minute	$0.96	
compression by Brand Communications		

MOOS Science Experiments - **Data ONLY** Continuous Throughput Requirements

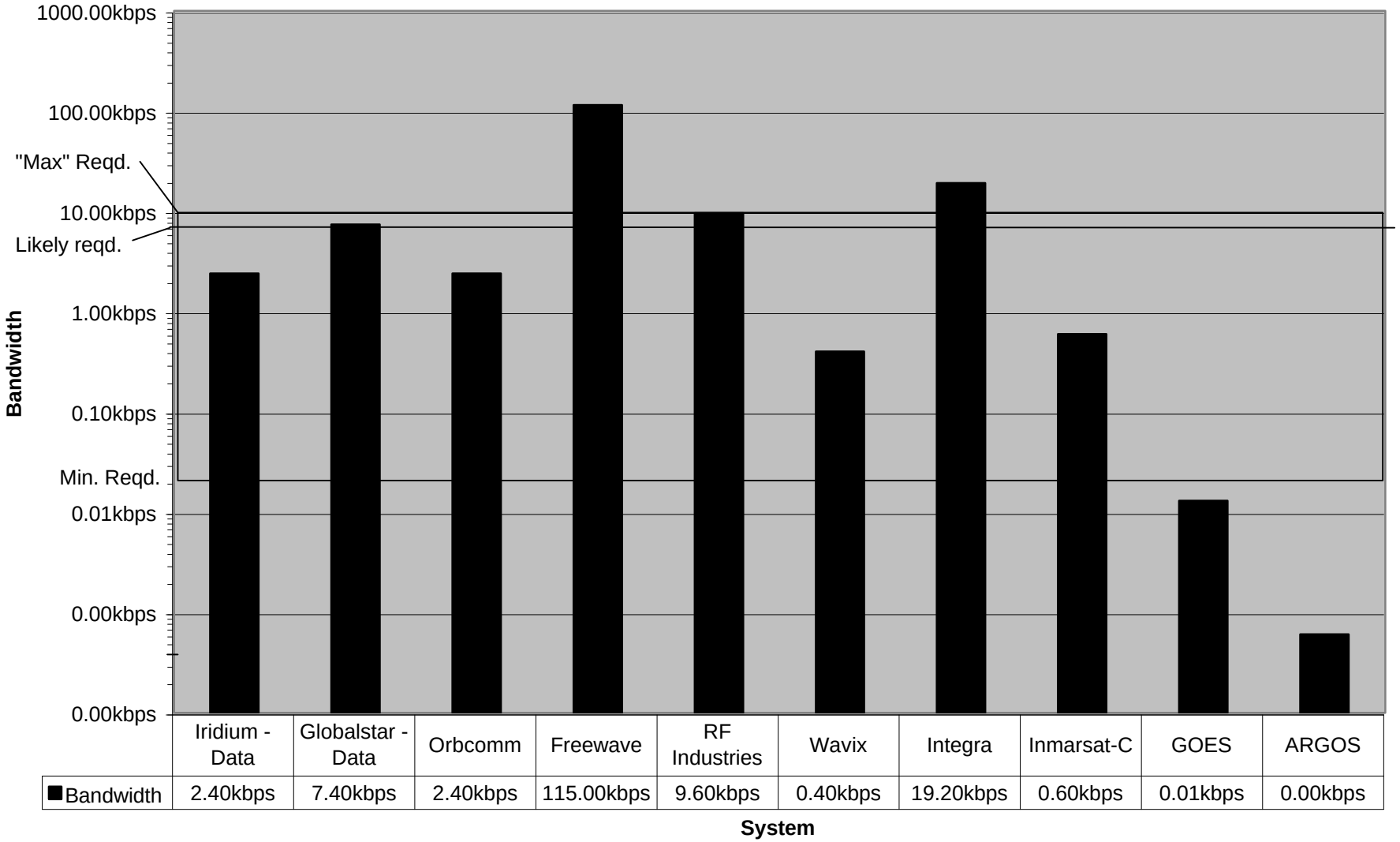


	All possible instruments	Multi-scale Oceanographic	Canyon Processes - normal	Canyon Processes - event	Active Mid-ocean Ridge	Benthic Carbon cycles
Norm. Ave Data	97.00kbps	0.30kbps	0.02kbps	0.12kbps	6.60kbps	0.31kbps

Process

Min. Reqd.

Advertised Wireless Bandwidth with Requirements (without compression)



	Iridium - Data	Globalstar - Data	Orbcomm	Freewave	RF Industries	Wavix	Integra	Inmarsat-C	GOES	ARGOS
Bandwidth	2.40kbps	7.40kbps	2.40kbps	115.00kbps	9.60kbps	0.40kbps	19.20kbps	0.60kbps	0.01kbps	0.00kbps

System