ASPRS GUIDE TO LAND IMAGING SATELLITES

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INTRODUCTION

Purpose

- This report is posted to make the ASPRS members and the broader remote sensing user community aware of just how ubiquitous imaging the Earth from space has become due to the technical advances that have enabled the creation of multispectral mid resolution satellites for as little as $10 to 20 Million.
  - 13 countries have mid to hi resolution satellites in orbit
  - By the end of the decade there will be 20

Background

- This survey was initiated under MITRE/Mitretek contracts with NASA and the USGS in support of the 1995 ASPRS Satellite Conference. NOAA supported development of a data base web site and an updating in the 2002 period. (http://commavail.noaa.gov/controlcenter.cfm?ft=0

Sources

- All of the data are from open sources, all of the systems are defined as civil; the majority of the systems have web sites that contain detailed descriptions of the satellites and their sensors. Googling will find them and locate relevant news items.
- While the system definitions remain constant once announced the launch dates are highly volatile . History has shown that few satellites launch within 6 months of their initial launch date.

Data Availability

- Data availability is provided on the web sites. There is no central source that provides meta data on the scenes that have been acquired.

Note

- In comparing systems be aware that the quality of the radiometry is usually not available and is a variable that may be important for specific uses.

Corrections and/or additions will be gratefully accepted

OVERVIEW

- **This guide includes all civil land imaging satellites with resolutions equal to or better than 36 meters in orbit or currently planned to be in orbit by 2010.**
  - **Optical, 26 in orbit, 25 planned**
  - **Radar, 3 in orbit, 9 planned,**
- **There are two major resolution groups**
  - **18 high resolution systems (0.5 to 1.8 meter)**
  - **44 mid resolution systems (2.0 to 36 meter)**
- **They have greatly different coverage capabilities.**
  - **Hi-res swaths are in the 8 to 28 kilometer range**
  - **Mid-res swaths are generally between 70 to 185 kilometers except for the DMC's 600 Km swaths**
- **There are four privately funded systems in orbit, 3 US and 1 Israeli, all focused on the hi-res military market. A 5th commercial system, RapidEye of Germany, recently reached its financial goal and plans to serve broad area applications.**
- **The planned European satellites are labeled "Dual Purpose" meaning that their data will serve both military and civil users**.

Satellite Data for Science: Potential and Problems

Potential

- For scientists and policy makers interested in understanding land cover and land use change on the global continental, and regional scales the broad area coverage multispectral satellites similar to Landsat will probably be the most useful.
- Mid-resolution broad area coverage satellites

Now (14)	2008 (19)
Landsats 5 and 7	Landsat Gap-Filler
Terra	RapidEye A,B,C,D,E
IRS C& D, & ResourceSat-1	IRS ReSat 1&2 Carto 1
CBERS 2	CBERS 2B & 3
SPOTs 2 & 4 & 5	Spot 5
DMC Sats-Al, Bil, Nigeria, ,Uk	DMC Sats, China, Bil, UK, Vin, Top,Thai
	RocSat-2
	ALOS

- The German commercial RapidEye 5 satellite system's 6.5 meter 5 VNIR bands and weekly coverage could make it a major science tool by itself
- The 0.5 to 1 meter satellites should be able to provide much of the required land cover ground truth data, increasing the ease of global studies**.**

Problems

- Landsat 7 is the only one of these satellites programmed to collect and archive 4 sets of global land images every year. It is the only program that makes all of its data available to all for the cost of reproduction. (CBERS2 data are free to all Brazilians)
- There is no current or planned source of meta data on the scenes acquired by even this subset of satellites.
- There is no international agreement that would encourage global acquisition programs for scientific use.
- If all of these data are to be scientifically useful the international science community must aggressively pursue data interpretation comparability and cal/val studies.

Recent News (data not in charts)

- **“China to set up world's first* satellite constellation for disaster monitoring** SHANGHAI, April 27 (Xinhuanet)”
  - From 2005 to 2006, two small optical satellites and one small SAR satellite will revisit every 48 hours with 30 M res.
  - By 2010 four small optical satellites and four small SAR satellites will revisit every 12 hours.
  - “China expects to introduce international partners in the second phase…to fully play its role in disaster control in the world”
- **Brazil announces CBERS 2B in ‘05/’06 as gap filler SN 9/20**
  - Images available to all Brazilians at no cost
  - A commercial sales plan is under discussion
  - Images “might” be available for scientific requests
- **“Thailand signs deal with French company for spy satellite”** BANGKOK (AFP) Jul 19, 2004”
  - Said to be similar to RocSat which has 2 M res.
  - SPOT has world distribution rights (as it does for RocSat)
- **Maylasia will launch RazakSAT (ex MACSAT) in 10/05**
  - 2.5 M res in a 7 degree 685 Km orbit for frequent equatorial observations
- **NASA issued RFI on 8/5/04 for “a new Operational Land Imager (OLI) for the NPOESS”**
  - OLI with ETM bands - thermal + 433 & 1375 nm bands
  - Pan at 10 meters, 177 km swath, 17 day repeat
  - To orbit on 828 km NPOESS sat. and/or gap filler mission
- **White House approves adding OLI to NPOES in 2010 and is considering a gap filler mission in 2008.**

Recent News (continued)

The following is being provided without comment except that both the data technology and the launch date seem to to be very ambitious.

- **Tuyuan China Surveyor Satellite Constellation**
- *Tuyuan has launched an open competition for its Surveyor SAR Crop Satellite Constellation*

- (PRWEB) September 2, 2004 -- A unique and entirely commercial “Surveyor” SAR satellite constellation comprising 5 low-cost medium C Band sensors has been placed under a global design competition by Tuyuan Technologies for launch in 2007. Tuyuan’s satellite crop streamer service represents the first focused satellite enterprise on global coverage for food crops and food security. Full Earth surface coverage by two of the five satellites will be achieved in less than 14 days and provides for the measurement of the effects of floods and other episodic events as they impact on global food crops. The five satellites that comprise the constellation has a continued in-built design redundancy on one satellite and will scan the Earth’s surface returning telemetry that will be processed automatically and streamed into Tuyuan’s financial, commodity’s’ industry and government clients in real-time mode.

- The SAR on-board buses, configurations and sensors are all identical and focus on two resolutions of 10 meter and 25 meter with no high resolution mode. Swath widths are to be designed at 100 and 250 kilometers respectively thus bringing an extremely high cost benefit ratio in low risk terms.

A GUIDE TO THE CHARTS

- **Table by best resolution**
  - **Could be titled the rush to hi-resolution and radar**
  - **Note that there are no US radar satellites**
- **Hi-Res schedule**
  - **Note that 7 countries are involved and the very aggressive plans for 1 meter radar in Europe**
- **Mid-Res schedule**
  - **There are 18 countries funding satellites.**
  - **Germany's RapidEye is the only commercial system.**
- **Sensor characteristics**
  - **Provides the number, location and resolution and swaths of the optical sensor bands and the resolution, swath ranges and bands of the radars**
  - **Note that most of the foreign Landsat-like systems carry 2 or more sensors, one of which is wide field of view**
- **Spatial coverage**
  - **Illustrates the scene coverage relative to Landsat's 185 x 170 Km scene. Chart courtesy of the USGS**
- **Spectral coverage**
  - **Shows the spectral location and range of the bands. Note the similarity of the spectral band widths**

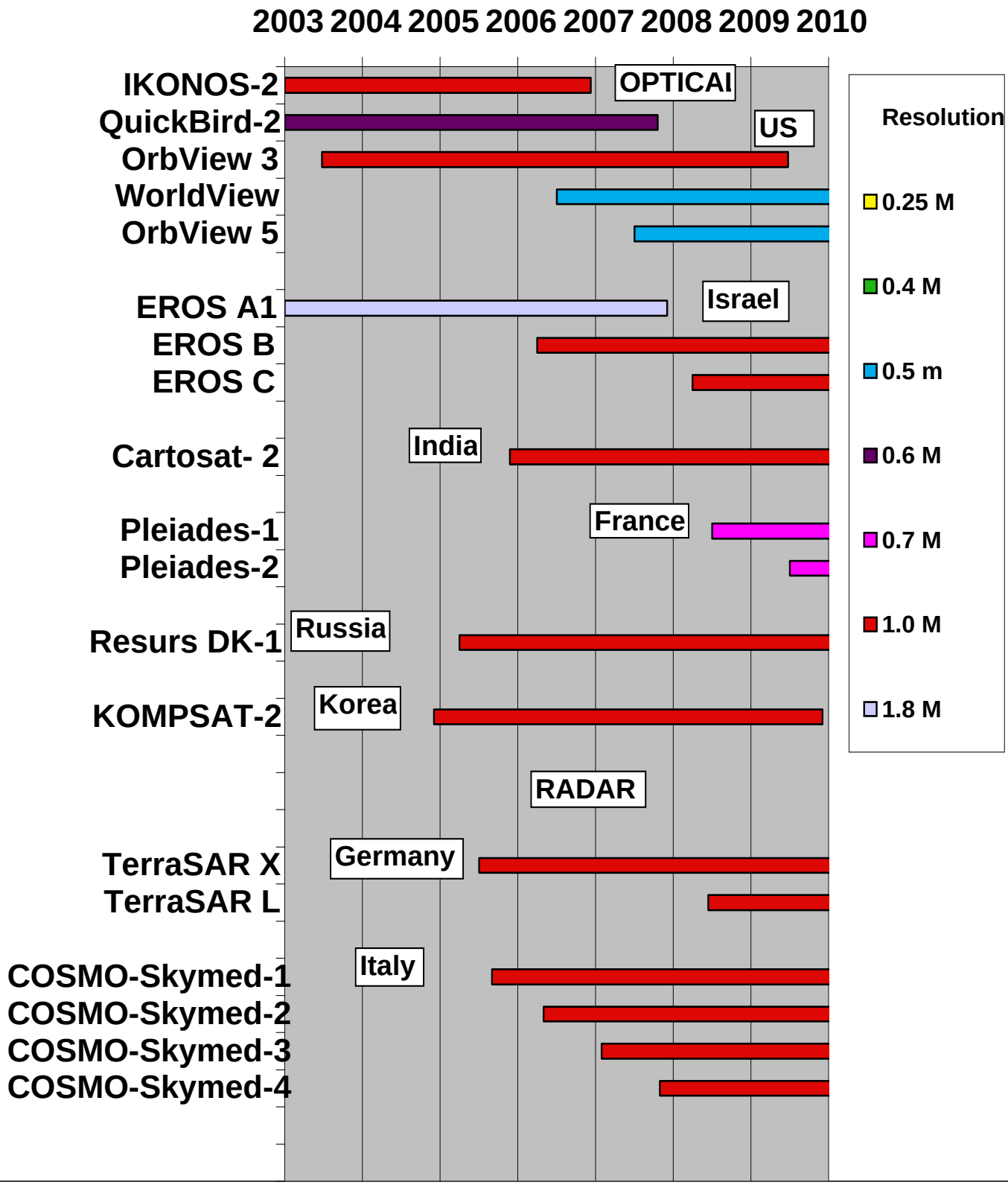
CURRENT AND PLANNED, 36 M & BETTER, LAND IMAGING SATELLITES

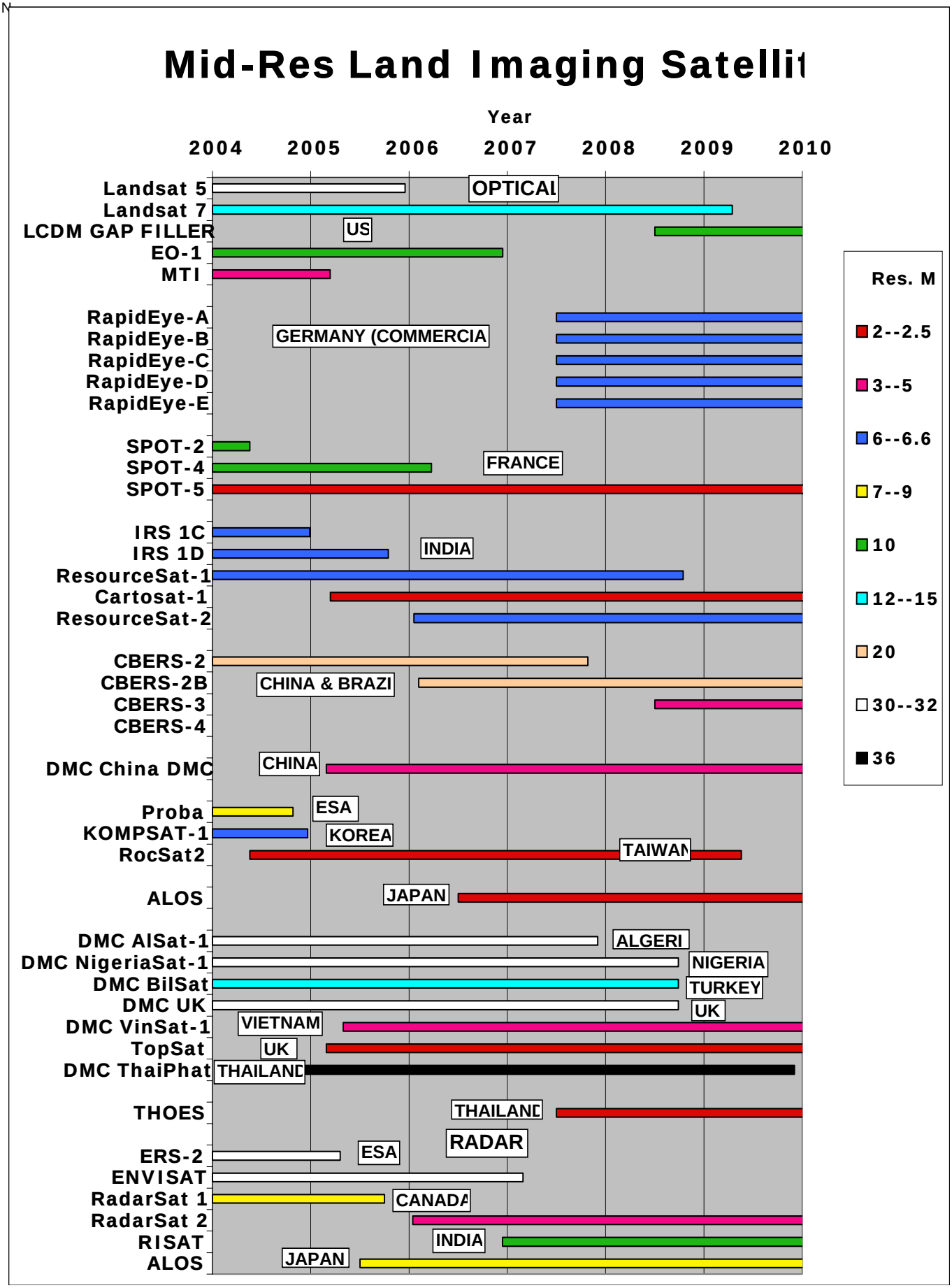
SATELLITE	COUNTRY	LAUNCH	PAN RES. M	MS RES. M	SWATH KM
OPTICAL					
OrbView 5	US	07/01/07	0.41	1.64	?
WorldView	US	07/01/06	0.5	2	16
QuickBird-2	US	10/18/01	0.6	2.5	16
EROS B	*Israel**	03/01/06	0.7		7
EROS C	*Israel**	03/01/08	0.7	2.5	16
Pleiades-1	France	07/01/08	0.7	2.8	20
Pleiades-2	France	07/01/09	0.7	2.8	20
IKONOS-2	US	09/24/99	1.0	4	11
OrbView 3	US	06/26/03	1.0	4	8
KOMPSAT-2	Korea	12/20/04	1.0	4	15
Resurs DK-#1	Russia	03/01/05	1.0	3	28
IRS Cartosat 2	India	12/10/05	1.0		10
EROS A1	*Israel**	12/05/00	1.8		14
RocSat2	Taiwan	04/20/04	2.0	8	24
THOES	Thailand	06/30/07	2.0	?	?
SPOT-5	France	05/04/02	2.5	10	120
TopSat (SSTL)	UK	03/01/05	2.5	5	10, 15
IRS Cartosat 1	India	03/15/05	2.5		30
RazakSat*	Malysia	06/15/05	2.5	5	?
ALOS	Japan	06/01/05	2.5	10	35, 70
DMC China DMC	China	03/01/05	4.0	32	600
MTI	US	03/12/00		5, 20	12
CBERS-3	China/Brazil	05/01/08	5.0	20	60, 120
CBERS-4	China/Brazil	06/01/10	5.0	20	60, 120
IRS 1C	India	12/28/95	6.0	23	70, 142
IRS 1D	India	09/29/97	6.0	23	70, 142
IRS ResourceSat-1	India	10/17/03	6.0	6, 23, 56	24, 140, 740
IRS ResourceSat-2	India	01/15/06	6.0	6, 23, 56	24, 140, 740
RapidEye-A	*Germany**	06/01/07		6.5	78
RapidEye-B	*Germany**	06/01/07		6.5	78
RapidEye-C	*Germany**	06/01/07		6.5	78
RapidEye-D	*Germany**	06/01/07		6.5	78
RapidEye-E	*Germany**	06/01/07		6.5	78
KOMPSAT-1	Korea	12/20/99	6.6		17
Proba	ESA	10/22/01	8.0	18, 36	14
MONITOR-E #1	Russia	12/15/2004 ?	8	20	1
SPOT-2	France	01/22/90	10.0	20	120
SPOT-4	France	03/24/98	10.0	20	120
EO-1	US	12/07/00	10.0	30	37
X-Sat	Singapore	01/15/06		10	50
LDCM	US	06/30/08	10.0	30	177
DMC BilSat (SSTL)	Turkey	09/27/03	12.0	26	52
Landsat 7	US	04/15/99	15.0	30	185
TERRA (ASTER)	Japan/US	12/15/99		1, 30, 90	60
CBERS-2	China/Brazil	10/21/03	20.0	20	113
CBERS-2B	China/Brazil	01/15/06	20.0	20	113
SICH-1M #1	Russia	12/15/2004 ?	24	24	48
Landsat 5	US	03/01/84		30.0	185
DMC AlSat-1(SSTL)	Algeria	11/28/02		32	600
DMC NigeriaSat-1 (SSTL)	Nigeria	09/27/03		32	600
DMC UK (SSTL)	UK	09/27/03		32	600
DMC VinSat-1	Vietnam	05/01/05		32	600
DMC ThaiPhat (SSTL)	Thailand	12/01/04		36	600
Tsinghua-1 (SSTL)	China	06/28/00		39	600
*** Only satellite in eqatorial orbit**					
RADAR					
RadarSat 1	Canada	11/04/95	8.5		
RadarSat 2	Canada	01/15/06	3.0		
ERS-2	ESA	04/21/95	30.0		
ENVISAT	ESA	03/01/02	30.0		
TerraSAR X	Germany	04/15/06	1.0		
TerraSAR L	Germany	06/15/08	1.0		
RISAT	India	12/01/06	10.0		
COSMO-Skymed-1	Italy	09/01/05	1.0		
COSMO-Skymed-2	Italy	05/01/06	1.0		
COSMO-Skymed-3	Italy	02/01/07	1.0		
COSMO-Skymed-4	Italy	10/01/07	1.0		
ALOS	Japan	06/01/05	2.5		

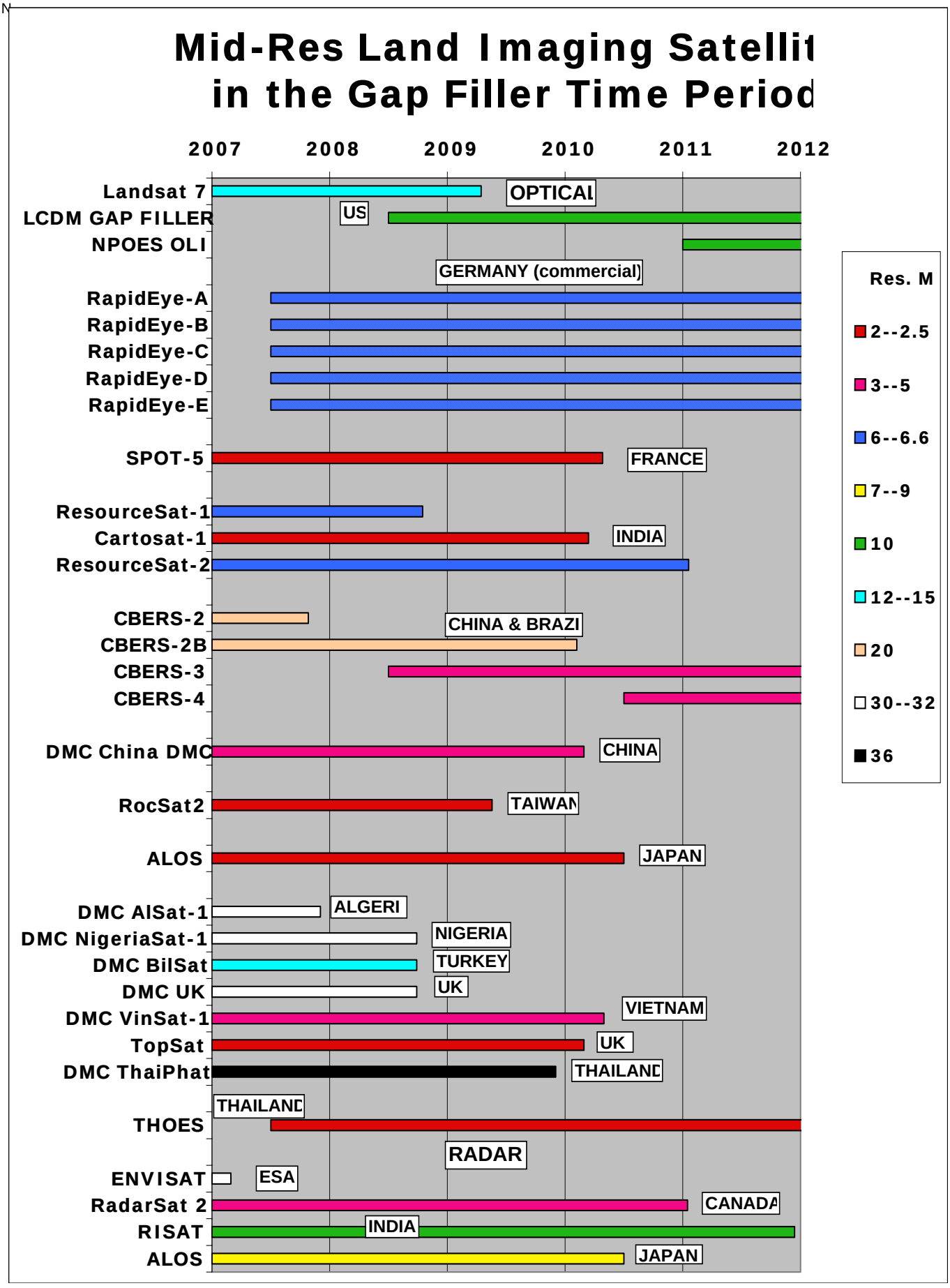
CURRENT AND PLANNED, 36 M & BETTER, LAND IMAGING SATELLITES

SATELLITE	COUNTRY	LAUNCH	PAN RES. M	MS RES. M	SWATH KM
	OPTICAL				
DMC AlSat-1(SSTL)	Algeria	11/28/02		32	600
Tsinghua-1 (SSTL)	China	06/28/00		39	600
DMC China DMC	China	03/01/05	4.0	32	600
CBERS-2	China/Brazil	10/21/03	20.0	20	113
CBERS-2B	China/Brazil	01/15/06	20.0	20	113
CBERS-3	China/Brazil	05/01/08	5.0	20	60, 120
CBERS-4	China/Brazil	06/01/10	5.0	20	60, 120
Proba	ESA	10/22/01	8.0	18, 36	14
SPOT-2	France	01/22/90	10.0	20	120
SPOT-4	France	03/24/98	10.0	20	120
SPOT-5	France	05/04/02	2.5	10	120
Pleiades-1	France	07/01/08	0.7	2.8	20
Pleiades-2	France	07/01/09	0.7	2.8	20
RapidEye-A	*Germany**	06/01/07		6.5	78
RapidEye-B	*Germany**	06/01/07		6.5	78
RapidEye-C	*Germany**	06/01/07		6.5	78
RapidEye-D	*Germany**	06/01/07		6.5	78
RapidEye-E	*Germany**	06/01/07		6.5	78
IRS 1C	India	12/28/95	6.0	23	70, 142
IRS 1D	India	09/29/97	6.0	23	70, 142
IRS ResourceSat-1	India	10/17/03	6.0	6, 23, 56	24, 140,740
IRS Cartosat 1	India	03/15/05	2.5		30
IRS Cartosat 2	India	12/10/05	1.0		10
IRS ResourceSat-2	India	01/15/06	6.0	6, 23, 56	24, 140, 740
EROS A1	*Israel**	12/05/00	1.8		14
EROS B	*Israel**	03/01/06	0.7		7
EROS C	*Israel**	03/01/08	0.7	2.5	16
TERRA (ASTER)	Japan/US	12/15/99		15, 30, 90	60
ALOS	Japan	06/01/05	2.5	10	35, 70
KOMPSAT-1	Korea	12/20/99	6.6		17
KOMPSAT-2	Korea	12/20/04	1.0	4	15
RazakSat	Malyasia	06/15/05	2.5	5	?
DMC NigeriaSat-1 (SSTL)	Nigeria	09/27/03		32	600
MONITOR-E #1	Russia	12/15/2004 ?	8	20	94, 160
SICH-1M #1	Russia	12/15/2004 ?	24	24	48
Resurs DK-#1	Russia	03/01/05	1.0	3	28
X-Sat	Singapore	01/15/06		10	50
RocSat2	Taiwan	04/20/04	2.0	8	24
DMC ThaiPhat (SSTL)	Thailand	12/01/04		36	600
THOES	Thailand	06/30/07	2.0	?	?
DMC BilSat (SSTL)	Turkey	09/27/03	12.0	26	52
DMC UK (SSTL)	UK	09/27/03		32	600
TopSat (SSTL)	UK	03/01/05	2.5	5	10, 15
Landsat 5	US	03/01/84		30.0	185
Landsat 7	US	04/15/99	15.0	30	185
IKONOS-2	*US**	09/24/99	1.0	4	11
MTI	US	03/12/00		5, 20	12
EO-1	US	12/07/00	10.0	30	37
QuickBird-2	*US**	10/18/01	0.6	2.5	16
OrbView 3	*US**	06/26/03	1.0	4	8
OrbView5	*US**	07/01/07	0.41	1.64	?
WorldView	*US**	07/01/06	0.5	2	16
LDCM	US	06/30/08	10.0	30	177
DMC VinSat-1	Vietnam	05/01/05		32	600
	RADAR				
RadarSat 1	Canada	11/04/95	8.5		
RadarSat 2	Canada	01/15/06	3.0		
ERS-2	ESA	04/21/95	30.0		
ENVISAT	ESA	03/01/02	30.0		
TerraSAR X	Germany	04/15/06	1.0		
TerraSAR L	Germany	06/15/08	1.0		
RISAT	India	12/01/06	10.0		
COSMO-Skymed-1	Italy	09/01/05	1.0		
COSMO-Skymed-2	Italy	05/01/06	1.0		
COSMO-Skymed-3	Italy	02/01/07	1.0		
COSMO-Skymed-4	Italy	10/01/07	1.0		
ALOS	Japan	06/01/05	2.5		

Hi-Res Land Imaging Satelli




Mid-Res Land Imaging Satellit
Year
2004
2005
2006
2007
2008
2009
2010
Landsat 5
Landsat 7
LCDM GAP FILLER
EO-1
MTI
RapidEye-A
RapidEye-B
RapidEye-C
RapidEye-D
RapidEye-E
SPOT-2
SPOT-4
SPOT-5
IRS 1C
IRS 1D
ResourceSat-1
Cartosat-1
ResourceSat-2
CBERS-2
CBERS-2B
CBERS-3
CBERS-4
DMC China DMC
Proba
KOMPSAT-1
RocSat2
ALOS
DMC AlSat-1
DMC NigeriaSat-1
DMC BilSat
DMC UK
DMC VinSat-1
TopSat
DMC ThaiPhat
THOES
ERS-2
ENVISAT
RadarSat 1
RadarSat 2
RISAT
ALOS
OPTICAL
US
GERMANY (COMMERCIA
FRANCE
INDIA
CHINA & BRAZI
CHINA
ESA
KOREA
TAIWAN
JAPAN
ALGERI
NIGERIA
TURKEY
UK
VIETNAM
UK
THAILAND
THAILAND
RADAR
ESA
CANADA
INDIA
JAPAN
Res. M
2--2.5
3--5
6--6.6
7--9
10
12--15
20
30--32
36


Mid-Res Land Imaging Satellit
in the Gap Filler Time Period
2007
2008
2009
2010
2011
2012
Landsat 7
LCDM GAP FILLER
NPOES OLI
RapidEye-A
RapidEye-B
RapidEye-C
RapidEye-D
RapidEye-E
SPOT-5
ResourceSat-1
Cartosat-1
ResourceSat-2
CBERS-2
CBERS-2B
CBERS-3
CBERS-4
DMC China DMC
RocSat2
ALOS
DMC AlSat-1
DMC NigeriaSat-1
DMC BilSat
DMC UK
DMC VinSat-1
TopSat
DMC ThaiPhat
THOES
ENVISAT
RadarSat 2
RISAT
ALOS
OPTICAL
US
GERMANY (commercial)
FRANCE
INDIA
CHINA & BRAZI
CHINA
TAIWAN
JAPAN
ALGERI
NIGERIA
TURKEY
UK
VIETNAM
UK
THAILAND
THAILAND
RADAR
ESA
CANADA
INDIA
JAPAN
Res. M
2--2.5
3--5
6--6.6
7--9
10
12--15
20
30--32
36

SENSOR CHARACTERISTICS

OPTICAL SATELLITE	Sensor	Resolution Meters & (# bands) PAN	VNIR	SWIR	MWIR	TIR	Swath Kilometers
ALOS	AVNIR		10 (4)				70
	PRISM	2.5	(simultaneous fore, nadir, aft)				35, 70
CBERS-1, 2 & 2A	CCD	20.0	20 (4)				113
	IRMSS	80.0		80 (2)		160 (1)	120
	WFI-1		240 (3)				885
CBERS-3 & 4	IRMSS		40 (1)	40 (2)		80 (1)	120
	MUXCAM		20 (4)				120
	PANMUX	5.0	10 (3)				60
	WFI-2		73 (3)	73 (1)			866
DMC AlSat-1	MSDMC		32 (3)				600
DMC BilSat	MST		26 (4)				52
	PANT	12.0					
DMC China DMC	MSDMC		32 (3)				600
	PDMC	4.0					
DMC NigeriaSat-1	MSDMC		32 (3)				600
DMC ThaiPhat	TMS		36 (3)				600
DMC UK	MSDMC		32 (3)				600
DMC VinSat-1	MSDMC		32 (3)				600
	PDMC	4.0					
EO-1	ALI	10.0	30 (6)	30 (3)			37
	HYPERION		30 (230)				7.5
	LAC		250 (256)				250
EROS A1	PIC	1.8					14
EROS B	PIC-3	0.7					7
EROS C	PIC-2	0.7	2.8 (4)				11
IKONOS-2	OSA	1.0	2.5 (4)				11.3
IRS 1C & 1D	LISS-III		23.5 (3)	70.5 (1)			142
	PAN	6.0					70
	WiFS		188 (2)				810
IRS Cartosat 1	HR-PAN	2.5					30
IRS Cartosat 2	HR-PAN-2	1.0					10
IRS ResourceSat-1	AWiFS		56 (2)	56 (1)			740
IRS ResourceSat-2	LISS-III +		23.5 (3)	23.5 (1)			140
	LISS-IV	6.0	6 (3)				70/23.9
KOMPSAT-1	EOC	6.6					17
	OSMI		1000 (6)				800
KOMPSAT-2	MSC	1.0	4 (4)				15

Note: Black = Operational. Red = Planned Revised 11/8/04 W.E.S.

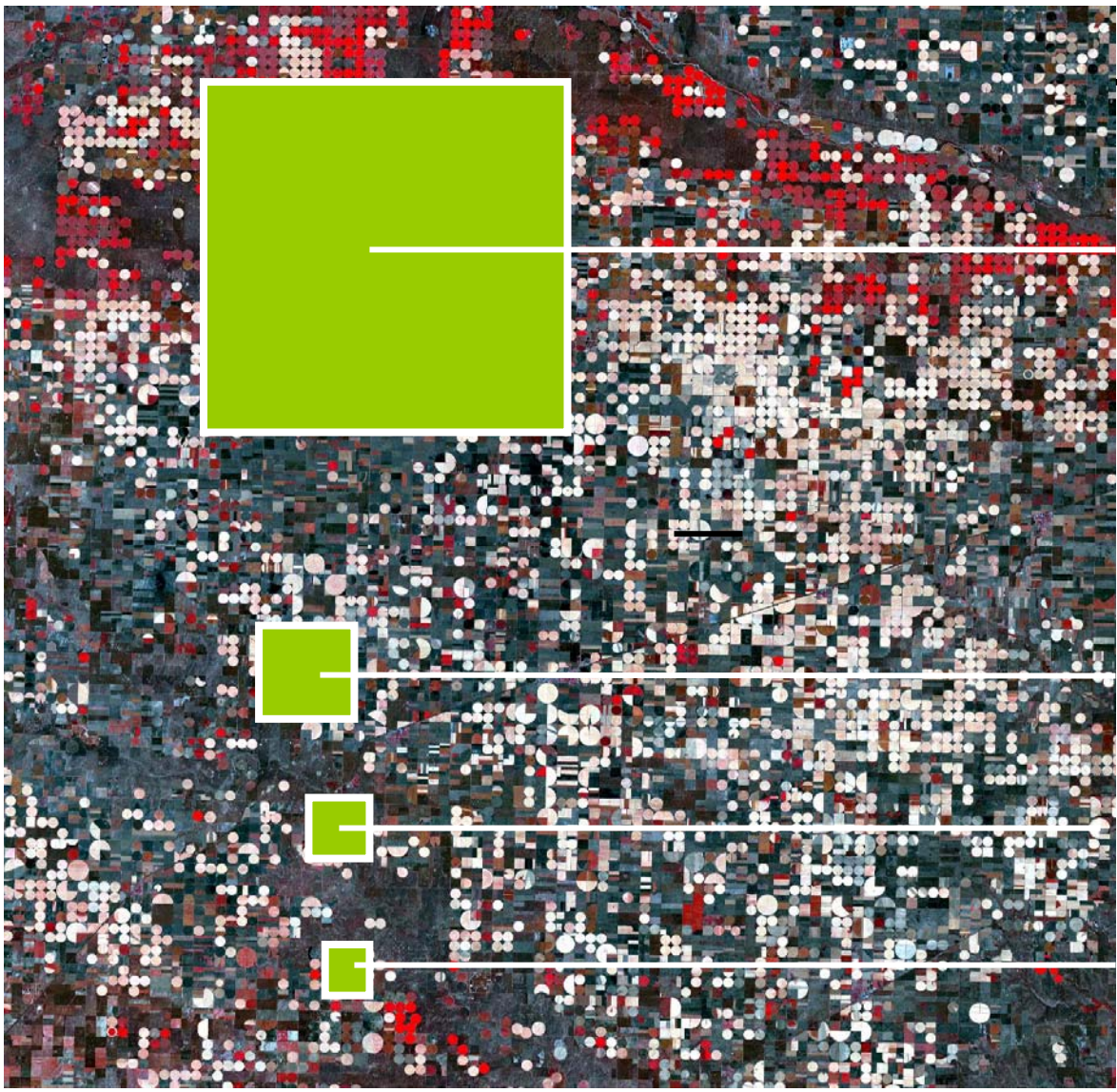
SENSOR CHARACTERISTICS (continu

OPTICAL SATELLITE	Sensor	Resolution Meters & (# bands) PAN	VNIR	SWIR	MWIR	TIR	Swath Kilometers
Landsat 5	MSS		80 (4)				185
	TM		30 (4)	30 (2)		120 (1)	185
Landsat 7	ETM+	15.0	30 (4)	30 (2)		60 (1)	185
LDCM	OLI	10.0	30 (5)	30 (3)			177
MONITOR-E #1	PANIMAGER	8.0					94
	MS DA		20 (3)	(40 TO DIST SITES)			160
MTI	MTI		5 (4),20 (3)	20 (3)	20 (2)	20 (3)	12
OrbView 3	OHRIS	1.0	4(4)				8
OrbView 5	OHRIS+	0.4	1.64 (4)				?
Pleiades-1 & 2	OHRI	0.7	2.8 (4)				20
Proba	CHRIS		18/36 (63)				14
	HRC	8.0					
QuickBird-2	BGIS 2000	0.6	2.5 (4)				16
RapidEye-A, B, C, D & E	REIS	6.5	6.5 (5)				158
RazakSat	MAC	**2.5**	5(?)	7 deg. equatorial orbit			?
Resurs DK-1	HROI	1.0	3 (3)				28
RocSat2	RSI	2.0	8 (4)				24
SICH-1M #1	MSU-EU		24 (3)				48
SPOT-1 & 2	HRV	10.0	20 (3)				120
SPOT-4	HRVIR	10.0	20 (3)	20 (1)			120
	VMI		1150 (3)	1150 (1)			2200
SPOT-5	HRG	2.5	10 (3)	20 (1)			120
	HRS	10.0					120
	VMI		1150 (3)	1150 (1)			2200
Terra	ASTER (VNIR)		15 (3)				60
	ASTER (SWIR)			30 (9)			60
	ASTER (TIR)					90 (5)	60
THOES	?	2.0	? (?)				?
TopSat	HIROC	2.5	5 (3)				15/10
Tsinghua-1 (SSTL)	?		39 (3)				600
WorldView	?	0.5	4 (8)				16

RADAR SATELLITE		Resolution Meters	(Band)	
ALOS	PALSAR	10-20-100	L	35-50-70-250
COSMO-Skymed-1,2,3,4	SAR-2000	1.0	X	
ENVISAT	ASAR	30.0	C	60-100
ERS-2	GOME	25.0	C	100
RadarSat 1	SAR	8.5-100	C	50-500
RadarSat 2	SAR+	3-28-100	C	20-100-500
RISAT	SAR	10-50	C	10-240
TerraSAR L	LSAR	1.5-30	L	10-200
TerraSAR X	XSAR	**1.5-30**	X	10-200

Note: Black = Operational Red = Planned Revised11/8/04 W.E.S

Spatial Coverage



BAND LOCATIONS FOR 30 METER AND BETTER SATELLITES