Chapter 2
Remote Sensing Satellites and Airborne Sensors

To develop an automated satellite image understanding system, the properties of satellite images should be known in advance. Therefore, this chapter introduces various remote sensing satellites and airborne systems. In almost all cases, the sensors on these satellites and airborne systems are called by the same name as the satellite or the airborne program. We follow the same convention.

The remote sensing satellites (sensors) we consider are Landsat, SPOT, IRS, AVHRR, Ikonos, Quickbird, FORMOSAT, CARTOSAT, Worldview, Alos, and Geoeye; the aerial sensors (programs) we consider are Daedalus, AVIRIS, HYDICE, and DAIS 7915. Wherever possible, we give a brief historical development of the sensor family with the operation dates, resolution, and revisit interval. We also give the spectral properties of the latest sensor for each family. We tabulate this information as a sensor selection guide. At the last section, we summarize and compare the properties of these sensors and their usage through time to give a brief information to the potential user.

2.1 Landsat

One of the best known families of remote sensing satellites is Landsat. This is a US based sensor family that has evolved over time. The first satellite in this family, launched in 1972, was Landsat 1. It had two sensors, the Return Beam Vidicon (RBV) and the Multi Spectral Scanner (MSS). RBV was a television camera, replaced by the Thematic Mapper (TM) in Landsat 4 and 5. In the last two satellites, there are panchromatic (pan), Enhanced Thematic Mapper (ETM) and Enhanced Thematic Mapper Plus (ETM+) sensors (Table 2.1). This family remains active; its average resolution is around 15 meters with a 16 day revisit interval. Table 2.2 summarizes the spectral properties of the latest family member, Landsat 7.

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Table 2.1 History of the Landsat family

Satellite	Launch date	End of service	Resolution (m)	Rev. int. (days)
Landsat 1	7/23/1972	1/6/1978	RBV 80; MSS 80	18
Landsat 2	1/22/1975	2/25/1982	RBV 80; MSS 80	18
Landsat 3	3/5/1978	3/31/1983	RBV 30; MSS 80	18
Landsat 4	7/16/1982		TM 30; MSS 80	16
Landsat 5	3/1/1984		TM 30; MSS 80	16
Landsat 6	10/5/1993	10/5/1993	Pan 15; ETM 30	16
Landsat 7	4/15/1999		Pan 15; ETM+ 30	16

Table 2.2 Landsat 7 spectral range

Band	Spectral range (μm)	Resolution (m)
1	0.450 to 0.515	30
2	0.525 to 0.605	30
3	0.630 to 0.690	30
4	0.750 to 0.900	30
5	1.550 to 1.750	30
6	10.400 to 12.500	60
7	2.090 to 2.350	30
Pan	0.520 to 0.900	15

Table 2.3 History of the SPOT family

Satellite	Launch date	Resolution (m)	Rev. int. (days)
SPOT 1	2/22/1986	Pan 10; MS 20	26
SPOT 2	1/22/1990	Pan 10; MS 20	26
SPOT 3	9/26/1993	Pan 10; MS 20	26
SPOT 4	3/4/1998	Pan 10; MS 20	26
SPOT 5	5/4/2002	Pan 2.5 or 5; MS 10	26

2.2 SPOT

SPOT is a French–Belgian–Swedish joint remote sensing satellite family. SPOT 1, launched in 1986, offered 10 meter panchromatic (pan) and 20 meter multispectral (ms) images with a 26 day revisit interval. The newest member of the family has the same revisit interval with 2.5 or 5 meter panchromatic and 10 meter multispectral image resolution (Table 2.3). See Table 2.4 for the spectral properties of SPOT 5, the latest SPOT in the sky.

Table 2.4 SPOT 5 spectral range

Band	Spectral range (μm)	Resolution (m)
1	0.50 to 0.59	10
Pan	0.48 to 0.71	2.5 or 5

Table 2.5 The history of the IRS family

Satellite	Launch date	End of service	Resolution (m)	Rev. int. (days)
IRS 1A	3/17/1988	1992	72.5	22
IRS 1B	8/29/1991	1999	72.5	22
IRS 1C	12/28/1995	1997	Pan 5.8; MS 23.5	24
IRS 1D	9/29/1997	1997	Pan 5.8; MS 23.5	24
IRS 2A	2000		Pan 5–10; MS 23.5–70.5	24
IRS P2	10/15/1994	1997	Pan 5.8; MS 36.25	22
IRS P3	3/21/1996	1997	Pan 189; MS 523	5

Table 2.6 IRS spectral range

Band	Spectral range (μm)	Resolution (m)
1	0.50 to 0.59	23.5
2	0.62 to 0.68	23.5
3	0.77 to 0.86	23.5
4	1.55 to 1.70	70.5
Pan	0.50 to 0.75	5.8

2.3 IRS

IRS is the Indian remote sensing satellite family, first launched in 1988 with 72.5 meter resolution. Although other Indian remote sensing satellites were launched prior to IRS, this was the first Indian family to see extensive use. The latest family member, IRS 2A, has 5 to 10 meter panchromatic and 23.5 to 70 meter multispectral image resolution (Table 2.5). The spectral properties of the latest family member appear in Table 2.6.

2.4 AVHRR

Another US based sensor is the Advanced Very High Resolution Radiometer (AVHRR). This sensor family differs from previous sensors in both resolution and intended application. It has a fairly low resolution (around 1.1 km) and is basically used for vegetation and forestry studies (Table 2.7). The latest AVHRR sensor, NOAA-16, has 6 bands covering the visible, near-infrared, and thermal infrared.

Table 2.7 History of the AVHRR family

Satellite	Launch date	End of service	Resolution (km)
NOAA-6	6/79	11/86	1.1
NOAA-7	8/81	6/86	1.1
NOAA-8	5/83	10/85	1.1
NOAA-9	2/85	11/88	1.1
NOAA-10	11/86	9/91	1.1
NOAA-11	11/88	9/94	1.1
NOAA-12	5/91	12/94	1.1
NOAA-14	12/94		1.1
NOAA-15	5/98		1.1
NOAA-16	9/00		1.1

Table 2.8 History of the Ikonos family

Satellite	Launch date	End of service	Resolution (m)	Rev. int. (days)
Ikonos 1	4/27/1999	4/27/1999	Pan 1; MS 4	3
Ikonos 2	9/24/1999		Pan 1; MS 4	3

Table 2.9 Ikonos spectral range

Band	Spectral range (μm)	Resolution (m)
1	0.45 to 0.52	4
2	0.51 to 0.60	4
3	0.63 to 0.70	4
4	0.76 to 0.85	4
Pan	0.45 to 0.90	1

2.5 Ikonos

Ikonos is the first US based *commercial* remote sensing satellite. It has one of the highest image resolution publicly available, with one meter panchromatic and four meter multispectral images (Table 2.8). See Table 2.9 for the spectral properties of Ikonos 2.

2.6 Quickbird

Quickbird is another US based *commercial* remote sensing satellite. Quickbird, launched on 10/18/2001, offers 0.61 meter panchromatic (pan) and 2.44 meter multispectral (ms) images with a three day revisit interval. See Table 2.10 for the spectral properties of Quickbird.

Table 2.10 Quickbird spectral range

Band	Spectral range (μm)	Resolution (m)
1	0.45 to 0.52	2.44
2	0.52 to 0.60	2.44
3	0.63 to 0.69	2.44
4	0.76 to 0.90	2.44
Pan	0.45 to 0.90	0.61

Table 2.11 FORMOSAT spectral range

Band	Spectral range (μm)	Resolution (m)
1	0.45 to 0.52	8
2	0.52 to 0.60	8
3	0.63 to 0.69	8
4	0.76 to 0.90	8
Pan	0.45 to 0.90	2

2.7 FORMOSAT

FORMOSAT-2 is a Chinese remote sensing satellite launched on 05/21/2004. It offers two meter panchromatic (pan) and eight meter multispectral (ms) images with a one day revisit interval. See Table 2.11 for the spectral properties of FORMOSAT.

2.8 CARTOSAT

CARTOSAT is a recent India based remote sensing satellite launched on 05/05/2005. It only offers 2.5 meter panchromatic (pan) images with five day revisit interval.

2.9 Worldview

Worldview is a recent US based *commercial* remote sensing satellite family. The first member of this family offers 0.55 meter panchromatic images. The second member of this family offers 0.46 meter panchromatic and 1.8 meter multispectral images (Table 2.12). See Table 2.13 for the spectral properties of Worldview 2.

2.10 ALOS

ALOS is a Japanese remote sensing satellite launched on 01/24/2006. It offers 2.5 meter panchromatic (pan) and 10 meter multispectral (ms) images with a two day revisit interval. See Table 2.14 for the spectral properties of ALOS.

Table 2.12 History of the Worldview family

Satellite	Launch date	End of service	Resolution (m)	Rev. int. (days)
Worldview 1	9/18/2007		Pan 0.55	1.7
Worldview 2	10/08/2009		Pan 0.46; MS 1.8	1.1

Table 2.13 Worldview 2 spectral range

Band	Spectral range (μm)	Resolution (m)
1	0.400 to 0.450	1.8
2	0.450 to 0.510	1.8
3	0.510 to 0.580	1.8
4	0.585 to 0.625	1.8
5	0.630 to 0.690	1.8
6	0.705 to 0.745	1.8
7	0.770 to 0.895	1.8
8	0.860 to 1.040	1.8
Pan	0.450 to 0.800	0.46

Table 2.14 ALOS spectral range

Band	Spectral range (μm)	Resolution (m)
1	0.42 to 0.50	10.0
2	0.52 to 0.60	10.0
3	0.61 to 0.69	10.0
4	0.76 to 0.89	10.0
Pan	0.52 to 0.77	2.5

2.11 Geoeye

Geoeye is yet another US based *commercial* remote sensing satellite family. The active member of this family, launched on 09/06/2010, with a three day revisit interval offers 0.41 meter panchromatic and 1.65 meter multispectral images. The second member of this family has not been launched, yet. However, it is expected to offer 0.25 meter panchromatic images. See Table 2.15 for the spectral properties of Geoeye 1.

2.12 Airborne Image Sensors

There are various airborne sensors available to supplement satellites for remote sensing applications. These sensors have resolutions comparable to satellite based sensors. Their superiority is the range of the spectrum they sweep and the number of

Table 2.15 Geoeye 1 spectral range

Band	Spectral range (μm)	Resolution (m)
1	0.450 to 0.520	1.65
2	0.520 to 0.600	1.65
3	0.625 to 0.695	1.65
4	0.760 to 0.900	1.65
Pan	0.450 to 0.900	0.41

Table 2.16 Airborne sensors

Program	Resolution (m)	Spectral range (μm)	Total # of bands
Daedalus	25	0.42 to 14.00	12
DAIS 7915	3 to 20	0.40 to 12.60	79
HYDICE	1 to 4	0.40 to 2.45	210
AVIRIS	17	0.40 to 2.45	224

Table 2.17 Daedalus spectral range

Band	Spectral range (μm)	Resolution (m)
1	0.42 to 0.45	25
2	0.45 to 0.52	25
3	0.52 to 0.60	25
4	0.60 to 0.62	25
5	0.63 to 0.69	25
6	0.69 to 0.75	25
7	0.76 to 0.90	25
8	0.91 to 1.05	25
9	1.55 to 1.75	25
10	2.08 to 2.35	25
11 (High gain)	8.50 to 14.00	25
12 (Low gain)	8.50 to 14.00	25

spectral bands. However, they are limited by range and time. We summarize these sensors in Table 2.16 and give the spectral properties of the Daedalus sensor in Table 2.17.

2.13 Summary of the Chapter

Although sensor information is probably known to most readers, we include it here for two main reasons. First, to give a review of the sensor technology. Second, most

Table 2.18 Summary of the sensor properties

Sensor	Resolution (m)	Spectral range (μm)	Rev. int. (days)
Landsat	15	0.45 to 2.35	16
SPOT	2.5	0.50 to 1.75	5
IRS	5	0.50 to 1.70	5
Ikonos	1	0.45 to 0.85	3
Quickbird	0.61	0.45 to 0.90	3
FORMOSAT	2	0.45 to 0.90	1
CARTOSAT	2.5	N/A	5
Worldview	0.46	0.40 to 1.04	1.1
ALOS	2.5	0.42 to 0.89	2
Geoeye	0.41	0.45 to 0.90	3
Airborne	1 to 25	0.42 to 14.00	N/A

feature extraction methods directly depend on the resolution and spectrum the sensor offers. Therefore, an improvement in the sensor may lead to new methods in multispectral satellite image understanding. Let us first summarize (Table 2.18) and compare the latest family members of these sensors.

This table suggests the following conclusions. Worldview 2 and Geoeye have the highest resolution. Worldview 1 and Quickbird have the next highest resolution, followed by Ikonos and Airborne sensors. If the resolution is the most important parameter in system design, Worldview 2 seems to be the best choice available.

However, these sensors also differ in spectral range. Airborne sensors in general have the widest spectral range available. Landsat, SPOT, IRS, and Worldview 2 follow them. Although airborne sensors offer superior spectral range, they suffer from range and time (as mentioned previously). Therefore, Landsat is the optimal choice if the spectral and operational ranges are considered. However, if a higher spectral range is required, airborne sensors can be used for small geographic locations.

Worldview 2 is also superior in terms of revisit interval, followed by FORMOSAT, ALOS, Geoeye, and Ikonos. For applications requiring frequent updates, Worldview 2 offers the best solution; Landsat is the worst. Although Worldview 2 has a narrower spectral range than Landsat, its resolution and revisit interval makes this sensor attractive for most applications.

So, the potential user has a wide range of choices on the resolution, spectral range, and revisit interval he or she desires. Next, we group and count the published papers by the sensors they used in Fig. 2.1 in three year time intervals, starting from 1967 to 2002. This records the popularity of these sensors over time.

This figure indicates the popularity of the Landsat family through time, and there are many reasons for this popularity. One main reason is the high spectral range and moderate resolution Landsat offers. Another reason may be the availability of its images. Besides Landsat, airborne sensors and SPOT have also been used extensively. Since Ikonos, Quickbird, Worldview 2, and Geoeye 1 have been launched recently, they are not shown here. However, based on the above comparison these satellites

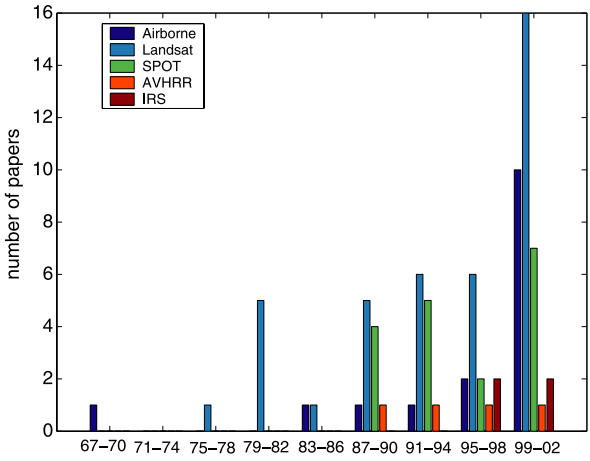

Fig. 2.1 Sensor usage in three year time intervals from 1967 to 2002

offer great promise for future remote sensing studies. The final, somewhat obvious, observation we can make is that overall use and study of remote sensing platforms shows near-exponential growth.

2.14 Problems

2.1 Summarize the satellite vs the country of origin.

2.2 What are the differences between satellite and airborne image capturing?

2.3 Based on the information provided in this chapter, plot

(a) The resolution of each satellite image vs its launch date.
(b) The revisit interval of each satellite vs its launch date.

2.4 (**Open ended question**) Using the plots in the previous problem, make projections on the properties of future satellites. Comment on your projections.

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