STATISTICAL STUDY OF SPACE REMOTE SENSORS

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WG I/4 - Airborne Digital Photogrammetric Sensor Systems

KEY WORDS: remote sensor, payload, statistical study, multispectral imagers, spectrometers, radiometers.

ABSTRACT:

Since the beginning of the space remote sensing, many instruments have been invented. The number of remote sensors and payloads are growing and becoming various increasingly. A mission designer usually has many options and different combinations of remote sensors to achieve their objectives. However there is a lack of elaborated investigation and statistical study of remote sensors. Thus it motivated us to make an extensive survey of remote sensors that are most used in earth observation and classify them in main categories. Then we made a descriptive statistical study that showed some useful relationship between some parameters. There are some good reasons and interpretations behind these relations that are investigated in this paper. It is expected this paper can help mission designers to make the best decision in selecting the appropriate sensors and also to predict their requirements in the early stages of the conceptual design.

1. INTRODUCTION

Statistical study plays an important role in early design stages. Payload sizing is indeed one of the major tasks in mission design that makes analogy with other existing remote sensors to estimate their own payload parameters. Thus a table of remote sensors, a purposeful classification and a statistical study of them is always the main requirement for mission designers.

To carry out the statistical study, a table of sample data is prepared which is mainly obtained from references [1] and [2]. Due to shortage of space, we have included all large tables at the end of the paper in appendix section. In order to validate the nature of the selected sample data, general features of the satellites and their sensors are studied in section 2. Then three most used sensors -that is multispectral imagers, radiometers and spectrometers- are investigated statistically in more detail in sections 3, 4 and 5.

2. SAMPLE DATA

The list of satellites used in this study can be seen in table1 [1] .This sample data contains just 50 remote sensing satellites out of around 600 total remote sensing satellites.

2.1 General Features

Before going through any detail study let us consider general characteristics of sample data that may affect the final results. The lunch years of satellites in table1 extend between 1975 and 2005 but most of them have lunched during 1995 to 2005. One of major ways to classify the satellites is categorizing them by their mass [3]. Table 2 shows one of the most popular ways for classifying satellites with respect to their mass.

Satellite Classification	Wet Mass	
Large Satellites	above 1000kg	
Medium Satellites	500 to 1000kg	
Mini Satellites	100 to 500kg	Small Satellites
Micro Satellites	10 to 100kg	
Nano Satellites	1 to 10kg	
Pico Satellites	0.1 to 1kg	
Femto satellite	Below 100g	

Table 2: satellite classification based on their mass [3]

Most of the satellites in table 1 are weighting from 1000 to 2000 which means they are mainly large satellites in aforesaid classification.

The last general feature of this sample data that may worth to consider is the orbit height namely Perigee and Apogee which predominantly differ from 700 to 900km.

2.2 Payload Features

Payloads of satellites in table1 have been extracted and classified in main categories and the population of each category has been computed. Figure1 shows ratio of each category in the study. As can be seen from this figure the maximum population belongs to multispectral imagers (22%), spectrometers (11%) and visible IR radiometers (10%). Therefore the special features of these most popular payloads will be considered statistically in the following sections.

[1] Due to shortage of space, we have included large tables at the end of the paper.

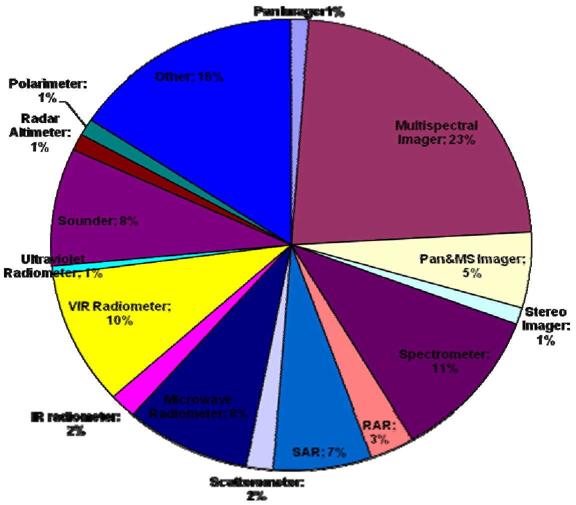

Figure 1: Ratio of each category of payloads

3. MULTISPECTRAL IMAGERS

Multispectral instruments acquire their images from the earth in a few specific regions of the electromagnetic spectrum which are called bands.[4] The increased spatial resolution and the addition of a spectral dimension allows for the discrimination of materials with this type of imagery. Although multispectral instruments can *discriminate* materials, a hyperspectral imager or spectrometer is required to actually *identify* materials. [4] The most significant parameters of these instruments are spatial resolution, size, weight, power and cost, as miniaturizing and introduction of new technologies have been of great interest over last century.

Table 3 shows a list of multispectral imagers belong to satellites listed in table1, with their mass, size, power and data rate.
As can be infer from the table, the values of mass and power for each imager are at the same range. This sample data covers light imagers from 0.14kg to heavy imagers of 270 kg with powers vary between 1.4W and 345W. Figure2 displays a histogram of mass and power. Considering this plot the most probable mass and power are 50kg and 50W respectively with the mean value of 91kg and 118W.

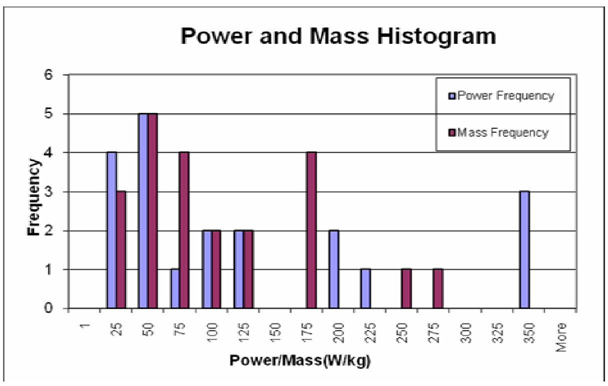

Figure 2: Power and mass histogram of multispectral imagers

Unfortunately there was lack of information for the imager size while collecting the sample data. Nonetheless the mean value of the size of imagers have been obtained to be 0.96m by computing the geometric mean value of height, width and length of each imager and then computing the arithmetic mean value of them.

Eventually let us consider the last parameter of table3 that is data rate the plot of which is illustrated in figure3. Based on this plot the most probable value of data rate is 4Mbit/sec and the mean value is 22.7Mbit/sec.

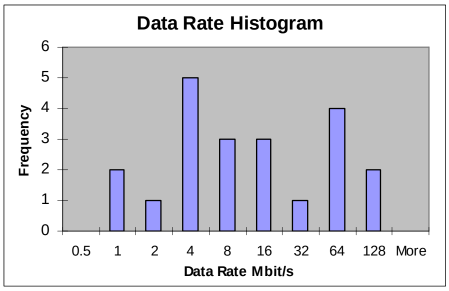

Figure 3: Data rate histogram of multispectral imagers

To analyze quality factors and parameters of imagers consider table4 in which the number of bands, resolution and swath width of each of mentioned imagers have been given.
As it is evidence at the first glance, most of the imagers work in visible and NIR region of spectrum. Plot in figure4 is resolution histogram for visible, NIR, SWIR and TIR. Noticing in diagram, it can be seen that the most probable resolutions are 50m, 50m, 100m and 1km for Visible, NIR, SWIR and TIR respectively.

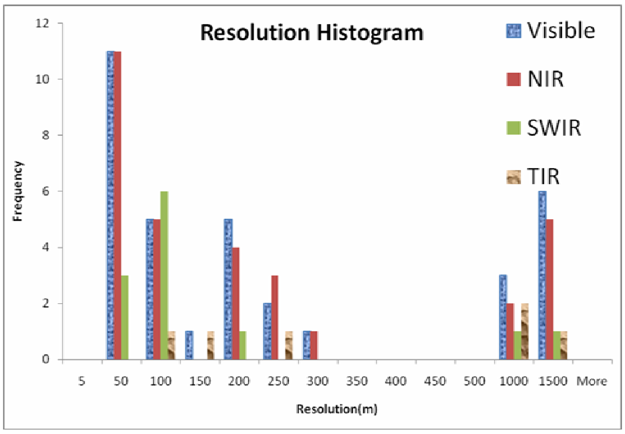

Figure 4: Resolution histogram of multispectral imagers

4. SPECTROMETERS

In remote sensing "spectrometry" or "spectroscopy" refers to the detection and measurement of radiation spectra of a target (area or volume) in many bands of the medium (generally the atmosphere).[1] In general spectroscopy is the science of measuring the spectral distribution of photon energies (as wavelengths or frequencies) associated with radiation that may be transmitted, reflected, emitted, or absorbed upon passing from one medium (vacuum or air) to another material objects.

In literature, the terms “imaging spectroscopy”, “imaging spectrometry” and “hyperspectral imaging” are often used interchangeably in remote sensing. Even though semantic differences might exist, a common definition is: *simultaneous acquisition of spatially coregistered images, in many, spectrally contiguous bands, measured in calibrated radiance units, from a remotely operated platform.[1]*

There are usually three “image capture” technologies of imaging spectrometers in use: Whiskbroom line array, Pushbroom area array and Framing camera.

As mentioned in last sections spectrometers are the most used payloads in space missions after multispectral imagers. Table 5 shows a list of spectrometers belong to satellites listed in table1, with their mass, power and data rate. Just like multispectral imagers, the values of mass and power for each spectrometer are at the same range. Figure 6 displays a histogram of mass and power in which the most probable mass and power are 200kg and 200W and the mean values of them are 140kg and 125W respectively.

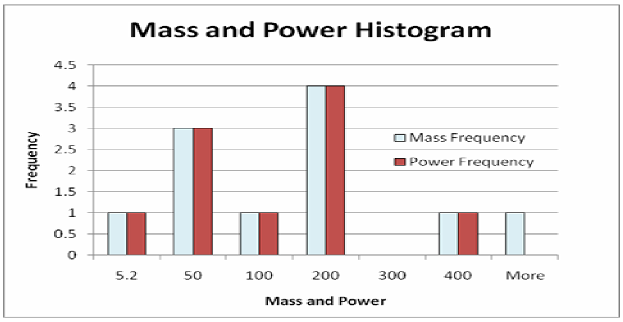

Figure 5: Mass and Power histogram of spectrometers

The histogram curve of data rate is illustrated in figure 6 in which it is evident that the most frequent data rate is 1000kbit/s.

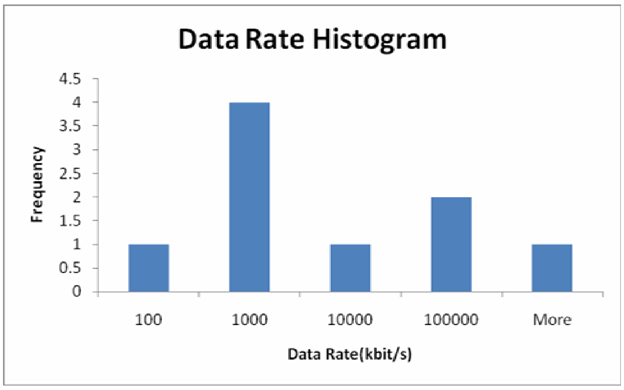

Figure 6: Data rate histogram of spectrometers

5. RADIOMETERS

Radiometry is the science of radiation measurement in any portion of the electromagnetic spectrum, i.e. the study of creation, transport, and absorption of electromagnetic energy, and the wavelength-dependent properties of these processes. The term radiometry is also often used to include the detection of the quantity, quality, and effects of such radiation.

Radiometer is an instrument that quantitatively measures the intensity of electromagnetic radiation in some bands within the spectrum. Usually, a radiometer is further identified by the portion of the spectrum it covers; for example, visible, infrared, or microwave. [1]

Looking at figure1, it can be seen radiometers particularly in Visible and IR region are the most common payload used in space missions after spectrometers. Table 6 shows a list of radiometers belong to satellites listed in table1, with their mass, size, power and data rate. As can be infer from the table, like multispectral imagers and spectrometers, the values of mass and power for each radiometer are at the same range. This sample data covers light radiometers of 33kg to heavy radiometers of 360kg with powers vary between 27W and 315W. Figure7 displays a histogram of mass and power. Considering this plot the most probable mass and power are 100kg and 100W and their mean values are 143kg and 93W respectively.

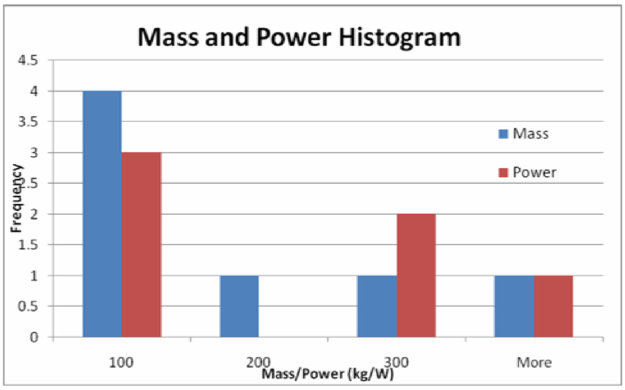

Figure 7: Power and mass histogram of radiometers imagers

To analyze quality factors and parameters of imagers consider table7 in which the number of bands, resolution and swath width of each of mentioned imagers have been given.

As it is evident at the first glance, most of the imagers work in visible and NIR region of spectrum. Investigation shows most of radiometers have used 8 bands in their instrument. Plot in figure 8 is resolution histogram for visible, NIR, SWIR and TIR. Noticing in diagram, you can see the most probable resolution is 1500m.

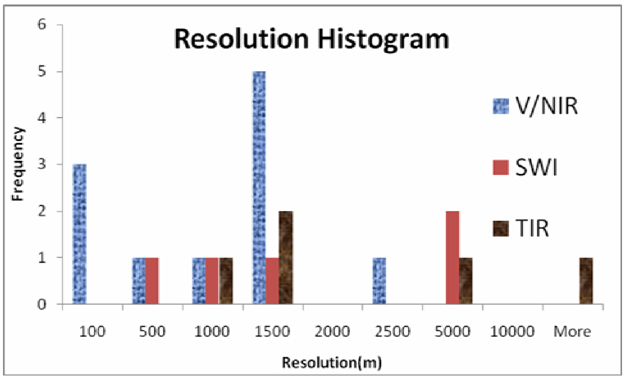

Figure 8: Resolution histogram of radiometers imagers

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4- Website: (http://www.es.ucsc.edu/%7Ehyperwww/chevron) last accessed: May2008

APENDIX

NO	year	Satellite	Country	Perigee (km)	Apogee (km)	Dry Mass(kg)	Payload Mass(kg)	Satellite Power(W)
1	1996	ADEOS1	Japan	804.6	789	3560	1300	4500
2	2002	ADEOS2	Japan	802.9	802.9	3500	1200	5300
3	1991	Almaz1	Russia	270	380	18550	3420	2400
4	2003	CBERS2	China & Brazil	778	778	1450		1100
5	1994	Electro	Russia	36000	36000	2580	900	1500
6	2002	Envisat 1	Europe	800	800	8140	2150	6500
7	1991	ERS 1	Europe	782	785	2384	888.2	2650
8	1988	FY-1B	China	900	900	750		800
9	1999	FY-1D	China	863	863	954		250
10	2000	FY-2B	China	36000	36000	600		280
11	2007	FY-3	China	836.4	836.4	2200		2480
12	1987	GEOS 7	US	36000	36000	399		450
13	1994	GEOS8	US	36000	36000	1140	247	1057
14	1995	GMS-5	Japan	36000	36000	746		300
15	2002	HY-1	China	795	795	365	87	450
16	1982	Insat 1A	India	36000	36000	650		
17	1992	Insat 2A	India	36000	36000	911		1180
18	2003	Insat 3A	India	36000	36000	1348		3100
19	1996	IRS P3	India	819	821	922		873
20	1999	IRS P4	India	720	720	1036		800
21	2005	IRS P5	India	618	618	1560		1100
22	2003	IRS P6	India	817	817	1360		1250
23	1991	IRS1B	India	867	913	975		700
24	1992	JERS	Japan	568	568	1340	497	2000
25	1978	Landsat3	US	901	920	891	58	515
26	1982	Landsat4	US	705	705	1941	303	990
27	1999	Landsat7	US	705	705	2020	288	1550
28	1997	Lewis	US	523	523	385.6		740
29	1975	Meteor2	Russia	950	950	1300	500	500
30	1985	Meteor3	Russia	1200	1200	2215	700	500
31	2001	Meteor3M	Russia	925	925	2500	900	1000
32	2002	Meteosat-8	Europe	36000	36000	2040		600
33	2002	Metsat-1	India	36000	36000	1055		550
34	1995	MicroLab	US	733	749	68		
35		Microlabsat	Japan	800	800	54		55
36	1987	MOS	Japan	909	909	738	149	
37	1988	NOAA11	US	848	865	1700	386	1500
38	1998	NOAA15	US	833	833	1454	100	
39	1980	Okean-E	USSR/Ukrainian	500	660	1950		
40	1999	Okean-O	Ukraine	670	670	6500	2000	5000
41	1988	Okean-O1_N3	Ukraine	630	660	1950	500	1100
42	1997	OrbView2	US	705	705	309	50	
43	2003	OrbView3	US	470	470	304		
44	1995	RADARSAT-1	Canadian	798	798	1540		3400
45	1998	Resurs-0 N4	Russia	663	691	1950	550	500
46	1999	Resurs-F3	Russia	260	275	6300		
47	2004	Sich-1M	Ukraine	285	650	2223		
48	1986	SPOT-1/2	France	832	832	1907	790	1000
49	1993	SPOT-3	France	832	832	1907		1000

NO	year	Satellite	Country	Perigee (km)	Apogee (km)	Dry Mass(kg)	Payload Mass(kg)	Satellite Power(W)
50	1998	SPOT-4	France	820	820	2550		2200
51	2002	SPOT-5	France	822	822	3030		2400

Table 1:List of Satellites used in the study [1] [2]

Payload	Sat	Mass (kg)	Size			Power(W)	Data Rate (kbit/s)
			L	W	H		
AWiFs	IRS P6	103.6				114	52500
CCD Camera	Insat 2E/3A	55				50	
CMR	Microlabsat	0.14	0.6	0.5	0.3	1.4	
COCTS	HY-1	50				41.7	
CZI	HY-1	15				30	2670
ISR	CBERS-3,4						26000
LISS 3	IRS P6	106.1				70	52500
LISS 4	IRS P6	169.5				216	105000
LISS I	IRS 1A/1B	38.5				34	5200
LISS I	IRS 1E	38.5				34	5200
LISS II A/B	IRS 1A/1B	80.5				34	10400
LISS II M	IRS P2	80.8				343	
LISS III	IRS 1C/1D	171				85	35790
MSS	Landsat1,2,3	64	1.27	0.58	0.53	50	15000
MSS	Landsat4,5	58				81	15000
MSU-E	Resurs-0 N3&N4	60					
MSU-K	Okean-O1_N3	6.5					
MSU-V	Okean-O						5120
SEVIRI	Meteosat-8	270	2.1	2.1	1	123	3000
TM	Landsat4,5	245	2	1.1	0.7	345	84900
Visible/IR TV	Electro						2560
VMI	SPOT-4	152	1	1	0.7	200	520
VMI	SPOT-5	152	1	1	0.7	200	520
WFI	CBERS-1/2						1100
WFI	CBERS-3,4						50000
WiFs	IRS 1C/1D	41				22	2060
WiFs	IRS P3	41				22	2060

Table 3: Technical parameters of multispectral imagers in the study[1] [2]

Payload	Sat	Band	Resolution(m)				Swath Width(km)
			visible	NIR	SWIR	TIR	
AWiFs	IRS P6	4	56	56	56		740
CCD Camera	Insat 2E/3A	3	1000	1000	1000		300
COCTS	HY-1	10	1100		1100	1100	1400
CZI	HY-1	4	250	250			500
IRS	CBERS-1/2	4	40	40	40	80	120
LISS 3	IRS-1C	4	23.5	23.5	70		148
LISS 3	IRS P6	4	23.5	23.5	23.5		140
LISS 4	IRS P6	3	5.8	5.8			140
LISS I	IRS 1E	4	72.5	72.5			148
LISS II A/B	IRS 1A/1B	4	36.25	36.25			74
LISS II M	IRS P2	4	32				66
LISS III	IRS 1C/1D	4	23.5	23.5	70.5		142
MR-2000M1	Meteor3M	1	700				3100
MSS	Landsat1,2,3	4	80	80	80		185
MSS	Landsat4,5	5	80	80	80		186
MSU-A	Okean-O	3	157	30			300
MSU-E	Resurs-0 N3&N4	3	45	45			45
MSU-E	Meteor3M	3	38	38			76
MSU-M	Okean-O	4	1500	1500			1930
MSU-M	Okean-O1_N3	4	1000	1000			1900
MSU-M	Sich-1M	4	1500	1500			2000
MSU-M	Sich-1M	4	1500	1500			2000

Payload	Sat	Band	Resolution(m)				Swath Width(km)
			visible	NIR	SWIR	TIR	
MSU-S	Meteor-Priroda	2	140	240			1380
MSU-S	Okean-O1_N3	2	250	250			1100
MSU-SK	Okean-O	5	157	157		590	600
MSU-SK	Okean-O	5	157	157		590	600
MSU-V	Okean-O	8	50	50	100	250	1380
TM	Landsat4,5	7	30	30	30	120	185
VMI	SPOT-5	4	1116	1116			
VMI	SPOT-5	4	1116	1116			
WFI	CBERS-1/2	2	260	260			885
WFI	CBERS-3,4	4	73	73			866
WiFs	IRS-1C	2	188	188			804
WiFs	IRS P3	3	188	188	188		804

Table 4: Image quality parameters of multispectral imagers in the study [1] [2]

Payload Name	Satellite	Mass(kg)	Power(W)	Data Rate (kbit/s)
GLI	ADEOS2	450	400	16000
GOME	ERS 2	55	32	40
GOMOS	Envisat 1	163	146	222
HIS	Lewis	23	50	327000
IMG	ADEOS1	150	150	600
JEA(ILAS2)	ADEOS2	130	80	500
MERIS	Envisat 1	200	175	24000
MIPAS	Envisat 1	320	195	533
MOS A	IRS P3	8.5		1300
TOMS	Meteor3	35	25	
XRS	Clark	5.2	5	

Table 5: Technical parameters of spectrometers in the study[1] [2]

Payload	Sat	Mass(kg)	Power(W)	Data Rate (kbit/s)
AVHRR	NOAA15	33	27	2000
AVNIR	ADEOS1	230	300	60000
MVISR	FY-1C/1D	95	45	665.4
OCM	IRS P4	75		20800
OCTS	ADEOS1	360	315	3000
OPS	JERS	174	250	60000
PLODER	ADEOS1	33	40	900

Table 6: Technical parameters of radiometers in the study [1] [2]

Payload	Sat	Band	Resolution(m)		
			visible	SWIR	TIR
AVHRR	NOAA15	6	1100	1100	1.1 km
AVNIR	ADEOS1	5	16		
MVISR	FY-1C/1D	5	1100		1100
OCM	IRS P4	8	236	236	
OCTS	ADEOS1	12	700	701	702
OPS	JERS	8	18		
PLODER	ADEOS1	15	6		
S-VISSR	FY-2C/2D		1250	5000	5000
VHRR	INSAT-2		2500		11000
VIRR	FY-3	10	1100		
VISSR	GMS-5	4	1250	5000	

Table 7: Image quality parameters of radiometers in the study [1] [2]