INTRODUCTION

This publication consists of 11 selected papers from workshops organized by the United Nations Office for Outer Space Affairs, within the framework of the Programme on Space Applications in 2004.

The Programme on Space Applications was established in 1971, with one of its main objectives to further general knowledge and experiences in the field of space technology between developed and developing countries. The Programme organizes around ten workshops, seminars and training courses on an annual basis for students and professionals from developing countries with the aim of increasing local capabilities in space technologies, thus helping to promote the peaceful use of outer space, in accordance with United Nations goals and principles. These activities bring together professionals from developed and developing countries and allow for an exchange of information in several space-related fields, including telecommunications, remote sensing and satellite applications, global environment and land resources management and international space regulations.

This volume of “Seminars of the United Nations Programme on Space Applications” is the sixteenth publication in an annual series that began in 1989. The selected papers discuss a variety of science policy issues and are published in the language of submission.

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I. APPLICATION-BASED THEMES

Space-based Data: Between Pure Science and Down-to-Earth Application in Indonesia

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Abstract

An unclear night or an unclear day are obstacles for ground-based solar observation. With that in mind, space-based data are very important to overcome such obstacles. Originally, the first work on space-based data was done by using Infra Red Astronomical Satellite (IRAS) data in analyzing young stellar objects (YSOs). In that connection, unbiased and almost all-sky coverage data are considerably important in studying the evolution of young stellar objects. Such pure science research can be conducted by using the online or CD-ordered data. In addition, for a developing country such as Indonesia, space science observation faces other problems such as lack of sophisticated observational facilities. Moreover, for any research budget proposal (except for university research projects), the application of the results directly or indirectly should also be included at a certain point in time. Besides having affordable facilities, such as small telescopes and data processing computers, space-based data are accessible through the Internet and considerably rich to be used in research for several applications. In addition to ground-based observation, solar physical, solar-terrestrial and physical space-based data are mainly used in the so-called "down-to-earth" research application on space sciences.

This paper discusses the utilization of space-based data for space science researches in Indonesia and its related problems. Firstly, space-based data and the problems in accessing it are briefly reviewed. Secondly, an example of utilizing space data for scientific research only is also discussed. Lastly, an example of "down-to-earth" research application is provided.

1. Introduction

Space researchers have been collecting and analyzing information received mainly by electromagnetic detectors. Unfortunately, not all ranges of electromagnetic radiation from space objects are able to reach ground-based observational instruments. Visible and radio waves are the two ranges of electromagnetic spectra that can be detected from the ground. However, clouds prevent good and effective results from observing outer space. Astronomical as well as solar physical observation need clear seeing.

Following recent progress made in the field of space technology, many orbiting observatories have been launched into outer space. Modern developments have become extremely important to overcome the limited number of days and nights normally used for space observation. Furthermore, space-based observatories can provide all ranges of electromagnetic spectra.

2. Space-based data

In general, space-based data can be divided into three groups: astrophysical, solar-physical and solar-terrestrial physical data. In order to mention some space-based data, a brief review will be provided.[1]

Radio–microwave–infrared observations have been performed by several space missions: Ariel 2, 3, and 4, Radio Astronomy Explorer (RAE) 1 (Explorer 38) and 2 (Explorer 49) (Nasa) Explorer 38 (RAE-1), Explorer 49 (RAE-2), The Very Long Baseline Interferometry (VLBI) Space Observatory Program (VSOP), RADIOASTRON, Cosmic Background Explorer (COBE), Submillimeter Wave Astronomy Satellite (SWAS), and Microwave Anisotropy Probe (MAP). MAP was launched into an orbit around the L2 Lagrange point of the Sun-Earth system. The Infra Red Astronomical Satellite (IRAS) has also conducted sky surveys. In addition, there is the Infrared Space Observatory (ISO). Other examples of infrared space observatories include the Spitzer Space Telescope (SST)/Space Infrared Telescope Facility (SIRTF), the Infrared Telescope Satellite/Space Flyer Unit IRTS/SFU, and the Midcourse Space Experiment (MSX).

In the visible spectrum there are the Hipparcos and the Hubble Space Telescope (HST). Hipparcos was the astrometrical satellite for measuring high precision parallaxes, while the HST is an excellent imaging facility. HST can also perform a great deal of observations at ultraviolet wavelengths. In addition, the International Ultraviolet Explorer (IUE) operates and observes ultraviolet radiation. Other examples of UV observatories are: Astron-1, Far UV Spectroscopic Explorer (FUSE) and Galaxy Evolution Explorer (GALEX).

High-energy observations in EUV, X-ray, and Gamma-ray have been condicted by several space missions, such as the Astronomical Netherlands Satellite (ANS), the Extreme Ultraviolet Explorer (EUVE), and the Array of Low Energy X-ray Imaging Sensors (ALEXIS). Other examples include the Rossi X-ray Timing Explorer (RXTE), the Advanced Satellite for Cosmology and Astrophysics (ASCA), Chandra X-ray Observatory (CXO), Uhuru, The Compton Gamma-Ray Observatory (CGRO), and many others.

Regarding solar physics research, several satellites have been sent into orbit. Ulysses, Yohkoh, the Transition Region and Coronal Explorer (TRACE), and the Solar and Heliospheric Observatory (SOHO) are examples of several satellites that observe the Sun continuously. Furthermore, the Geostationary Operational Environmental Satellite (GOES) produces data which are very important in studying solar-terrestrial physics.

In general, images and numerical data (including graphical plots data) are produced to be further analyzed. Several space-based data are now open to the public and can be accessed online via the Internet or distributed through CD-ROMs or other media. This is important since data access via the Internet is very useful to the scientific community. However, there is a problem of data access via the Internet depending on the bandwidth of the Internet connection, which is in turn related to

[1] (extracted from http://imagine.gsfc.nasa.gov/index.html,http://www.seds.org/~spider/oaos/oaos.html)

problems regarding research budget. The expensive, high speed Internet and the difficulties in downloading images from it, along with the lack of analyzing tools (e.g. expensive Interactive Data Language – IDL) are all elements that prevent scientists in Indonesia from actively utilizing the provided online data. Small size images could be the solution to this particular problem and could overcome such difficulties. Lastly, numerical data and GIF format plots are considerably helpful in providing online space-based data.

In Indonesia, the number of scientific researches is growing at universities and research institutions. However, for better results, scientific research should be combined with the so-called "down-to-earth" application at research institutions. Space science research should be in a position to produce more applicable results that could contribute to practical benefits to society as a whole. Solar-terrestrial physical data should be used for such a purpose.

3. Pure Science

There are a good number of space-based data that are helpful for scientists in developing countries who have to deal with lack of observational facilities to participate in space science research. Below is an example of using space-based data for a scientific purpose. IRAS data in CD-ROM format consist of unbiased flux data of point sources. The data were analyzed in order to introduce a new far-infrared Hertzsprung-Russel (H-R) diagram of YSOs. This diagram is useful to track the evolutionary stage of such objects.

The observed spectral energy distributions from far-infrared (FIR) to millimetre wavelengths of YSOs fit a modified blackbody radiation with a peak around 100 μm for both high- and low-mass YSOs. The spectra are nearly represented by the FIR colours made by IRAS flux densities at 60 and 100 μm. Using IRAS data, a FIR H-R diagram of cold YSOs is produced, the parameters of which are the FIR colour and the luminosity at 60 μm. In each FIR H-R diagram of YSOs of three nearby star-forming regions, YSOs in the early evolutionary phase form a fundamental sequence, along which they move increasing the luminosity while keeping the mass of FIR emitting envelope. The FIR H-R diagram of YSOs is useful for describing the luminosity evolution of YSOs in the protostar stage and for estimating the stellar masses of YSOs (Djamaluddin and Saito 1995, 1996, and references therein).

There are two fundamental lines on the FIR H-R diagram. For the modified blackbody radiation with a temperature T_d, one obtains a dust mass of the FIR emitting envelope, assuming dust properties. The dust mass is:

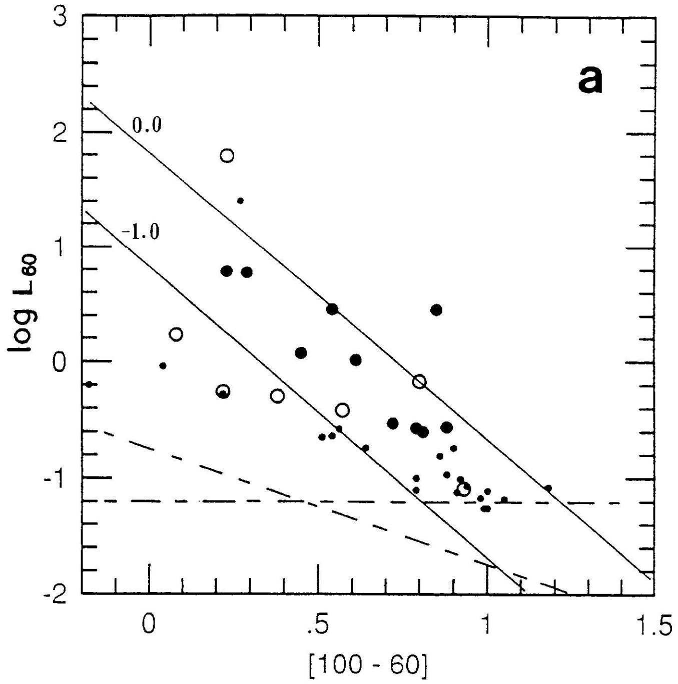
$$M_d \sim 1.4 \text{ x } 10^{-6} (0.48)^{\beta} d^2 f_{60} (e^{239.8/Td} - 1) M_o$$

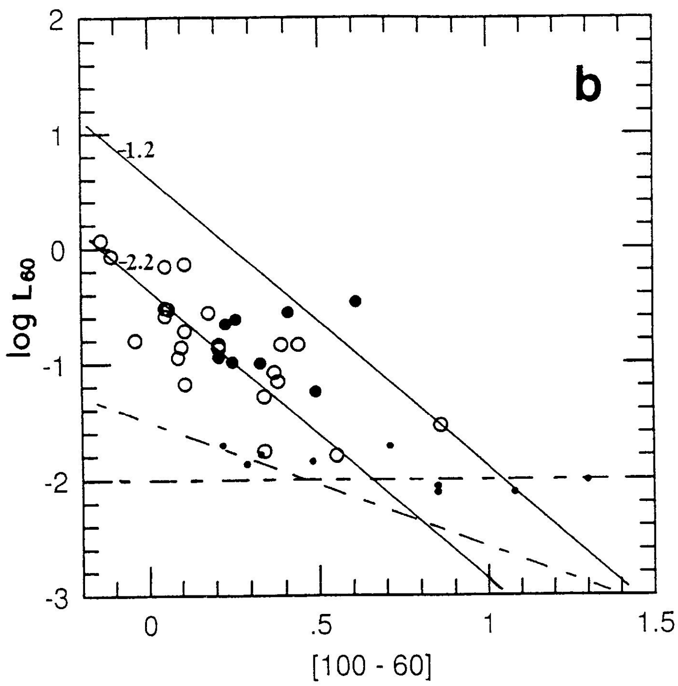
where β is dust emissivity (β=1 adopted), f_{60} is in Jansky (Jy) and the distance d is in kiloparsec (kpc). The locus of a constant M_d is a fundamental line on the FIR H-R diagram. Another fundamental line on the FIR H-R diagram is a relation between $[100 - 60] = \log(f_{100} / f_{60})$ and $d^2\ f_{60}$.

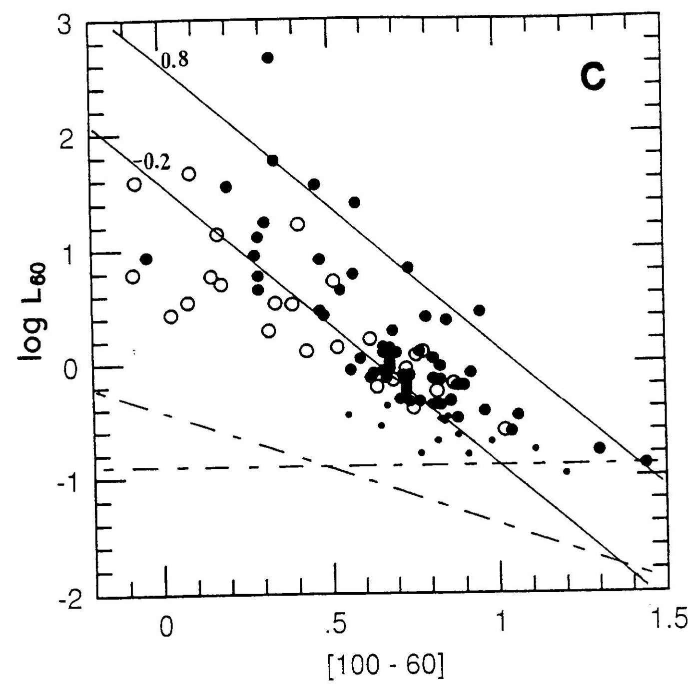
$d^2\ f_{60} \sim \{ ([100 - 60]\max + 0.222(3 + \beta))/([100 - 60] + 0.222(3 + \beta))\}^a$ x

$$\times \{(L_{max}/L_o)/0.31(4.578 + 1.762 \times 10^{[100-60]})\}$$

where [100 - 60]max is the colour at the maximum FIR luminosity of YSOs and *a* is a constant from 4 to 4 + β.

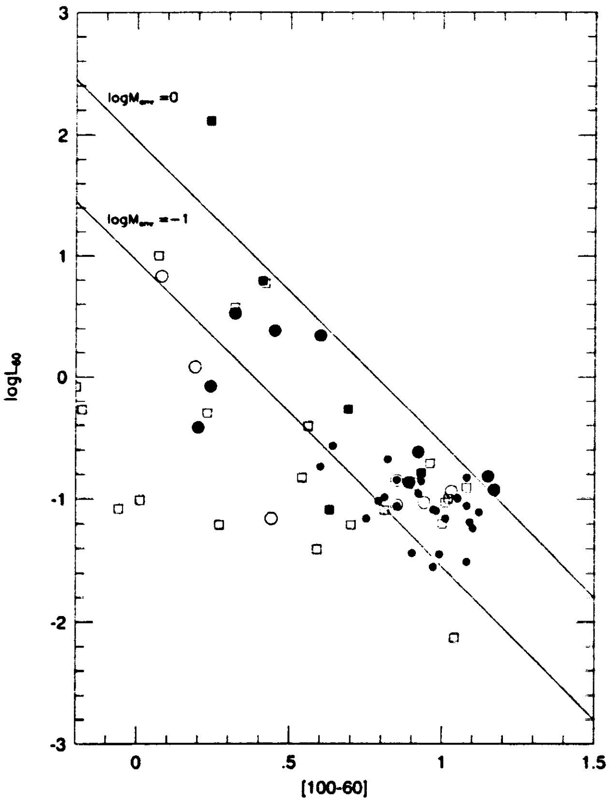






The FIR H-R diagrams of YSOs in the three star-forming regions of (a) Perseus-OB2, (b) Taurus, and (c) Orion molecular clouds, where the ordinate is $L_{60} = d^2\ f_{60}$ with the distance d in kpc and f_{60} in Jy and the abscissa is the FIR colour [100 - 60] = $\log(f_{100}/f_{60})$. The flux densities at 60 and 100 µm have good or moderate quality and the errors in plots are mostly less than 0.16. The YSOs are divided into three classes of the luminosity ratio L_f/L_m, where L_f is the luminosity for 30 to 135 ym and L_m is that for 7 to 30 pm; the filled circles denote the YSOs with $L_f/L_m > 4$, the open circles the YSOs with $L_f/L_m < 4$, and the dots the YSOs whose values of L_f/L_m cannot be determined whether or not they are larger than 4. The two solid lines in each diagram show the constant envelope-mass lines; the value of $\log(M_{env}/Mo)$ is shown on each line. On each diagram the horizontal dash-dotted line represents f_{60} = 0.5 Jy, and the inclined one f_{100} = 1.5 Jy, which are the IRAS sensitivity limits.

The FIR H-R diagram has been used by Kun (1998) to provide a further possibility to compare the Cepheus Flare with another star-forming complex. This diagram reveals that the coldest IRAS sources of a star-forming complex detected at 60 and 100 µrn populate a narrow region in the [100 - 60]-log L_{60} plane, along a constant value of the mass of the far-infrared-emitting envelope. Djamaluddin and Saito (1996) presented FIR H-R diagrams for the Taurus, Perseus OB2 and Orion complexes and defined two quantities characteristic of a star-forming region on the basis of the FIR H-R diagram: an envelope-mass interval, in which most of the youngest IRAS sources of a cloud complex are found and also a "typical largest mass". For comparison, the next figure shows the same diagram for the Cepheus Flare. It is apparent that the cold IRAS sources having [100 – 60]>0.6 can equally be recognized in the H-R diagram of Perseus OB2, Orion and the Cepheus Flare but are practically absent at Taurus. If these objects are small, having dense clumps within the clouds, then the reason for this peculiarity may be that the smallest clumps that can be formed with this [100 – 60] colour are resolved by IRAS at the distance of Taurus. The predominance of both low mass and low dust temperature among the Taurus cores may be a result of this selection effect.



FIR H-R diagram for the IRAS point sources in the Cepheus Flare. Large dots mark invisible sources with luminosity ratios of $L_f/L_m > 4$ and open circles denote invisible sources having $L_f/L_m < 4$. Filled squares are for visible stars with $L_f/L_m > 4$ and open squares for visible stars with $L_f/L_m < 4$. Small dots mark invisible sources detected only at 60 and 100 μm.

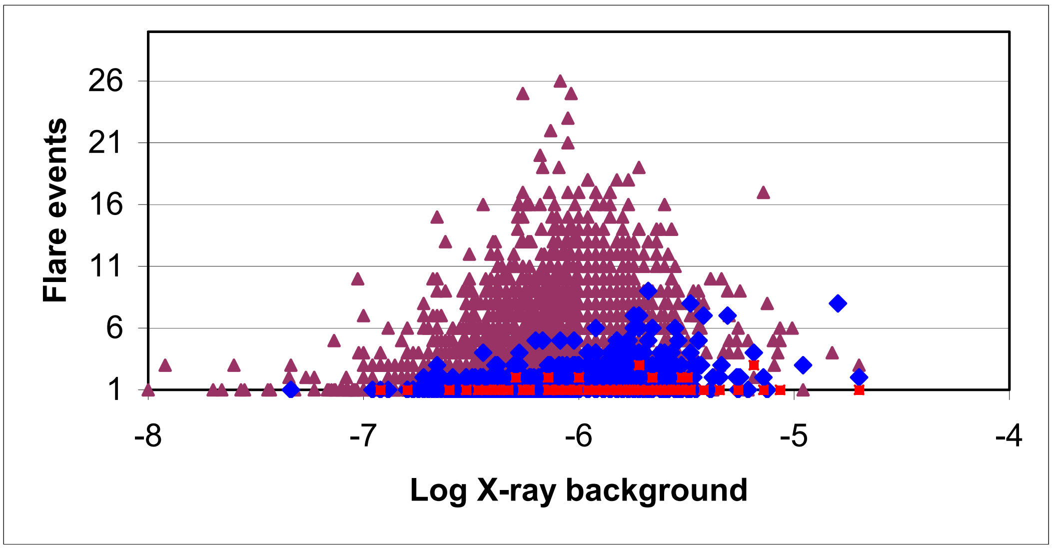
4. Down-to-Earth Application

One of the efforts to make down-to-earth applications on space science research is flare prediction; it is one of the most difficult in solar physics but has an impact on Earth. For such a prediction, GOES data of flare events and daily background X-ray flux data[2] are used to analyze trends of X-ray background flux as an indication of a possibility of major flare events. The background X-ray flux is classified as:

A: 10^{-8} Watts m^{-2}
B: 10^{-7} Watts m^{-2}
C: 10^{-6} Watts m^{-2}
M: 10^{-5} Watts m^{-2}
X: 10^{-4} Watts m^{-2}

For example, B1.2 = 1.2×10^{-7}, X1.1 = 1.1×10^{-4}

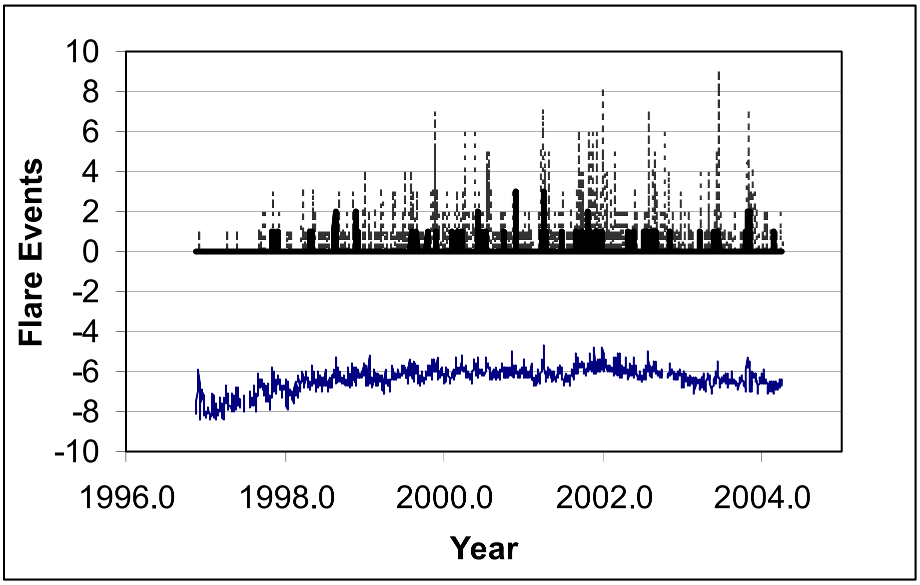
[2] (http://www.sec.noaa.gov)



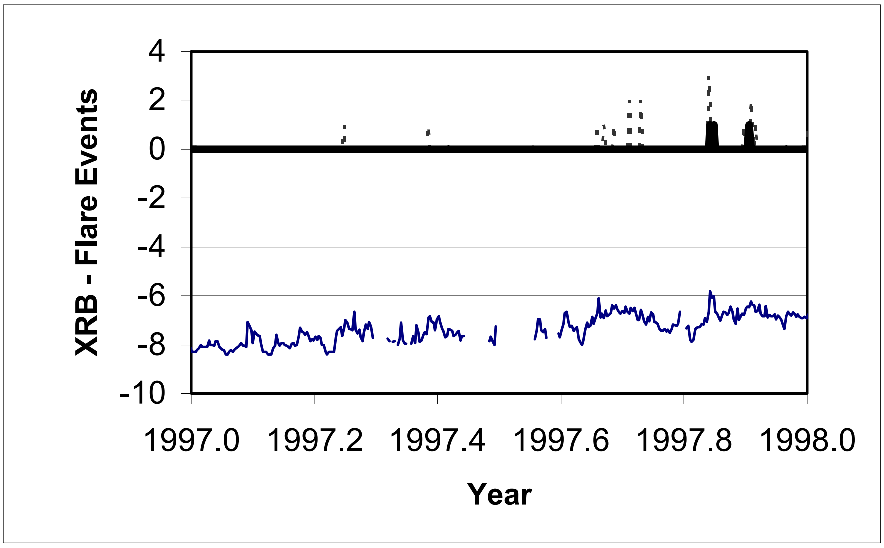
Squares denote X-class flare events, diamonds denote M-class flare events, and triangles denote C-class flare events.

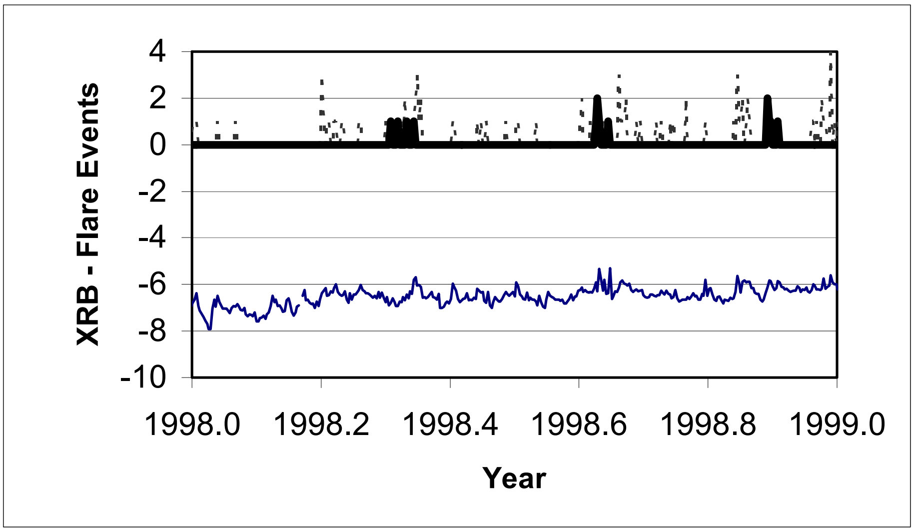
X-ray background flux	Flare events C	M	X
A (log X-ray <-7)	62	1	0
B (-7≤log X-ray<-6)	7046	455	28
C (-6≤log X-ray<-5)	4330	724	62
M (-5≤log X-ray<-4)	8	13	1

There is some indication that major flares (X-class) are never produced in the condition of X-ray background flux very low (A-class). This occurs mostly during X-ray background flux in B or C-classes, with the highest probabilities in C-class. It has also been found that the major flare events rarely occur during M-class X-ray background flux. As a result, during major flare events there is an energy release of about two to three orders of magnitude higher than the background level. These similar trends also occur for intermediate flare events (M-class). For low flare events (C-class) the energy release of about 1 order is higher than the background level. The next figures show the relationship between flare events and X-ray background flux.

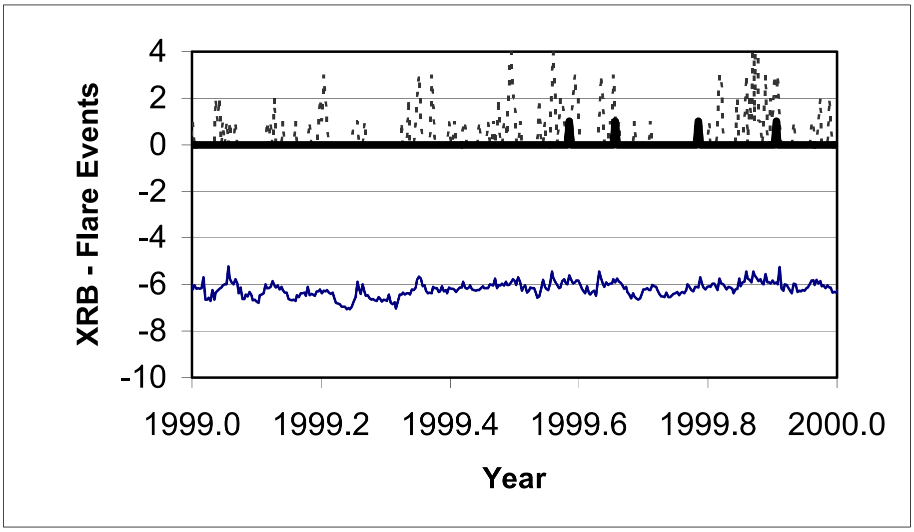


In general, X-ray background flux (lower graph) follows solar cycle with the minimum in 1996 and double peak in 2000 and 2002. The upper graph shows the flare events: thick line for flare X-class and dashed line for M-class. The following figures provide more detail for each year. This general analysis indicates that X-class and M-class flare events were preceded by the increasing of X-ray background flux.

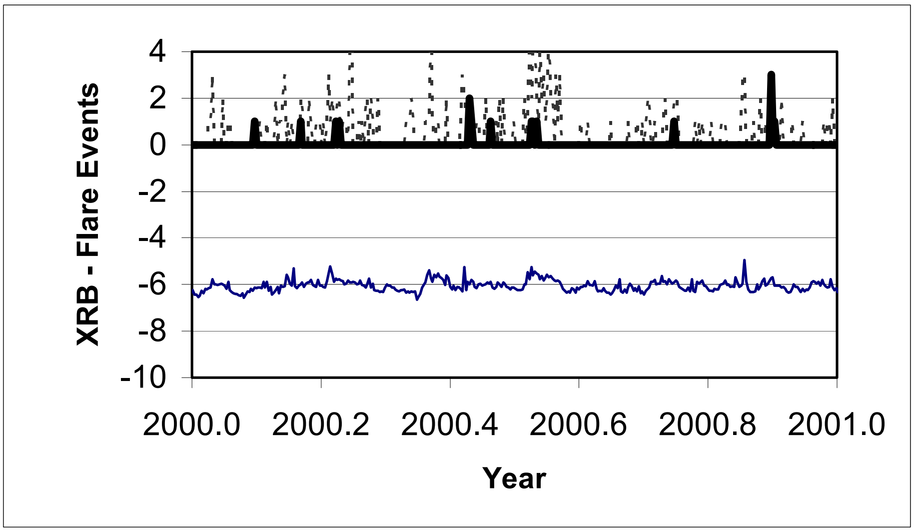




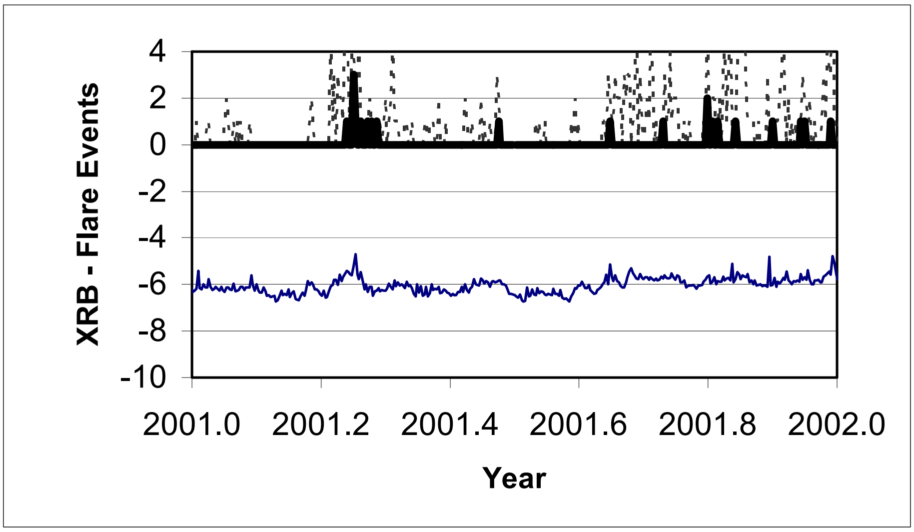
XRB - Flare Events
4
2
0
-2
-4
-6
-8
-10
1998.0
1998.2
1998.4
1998.6
1998.8
1999.0
Year



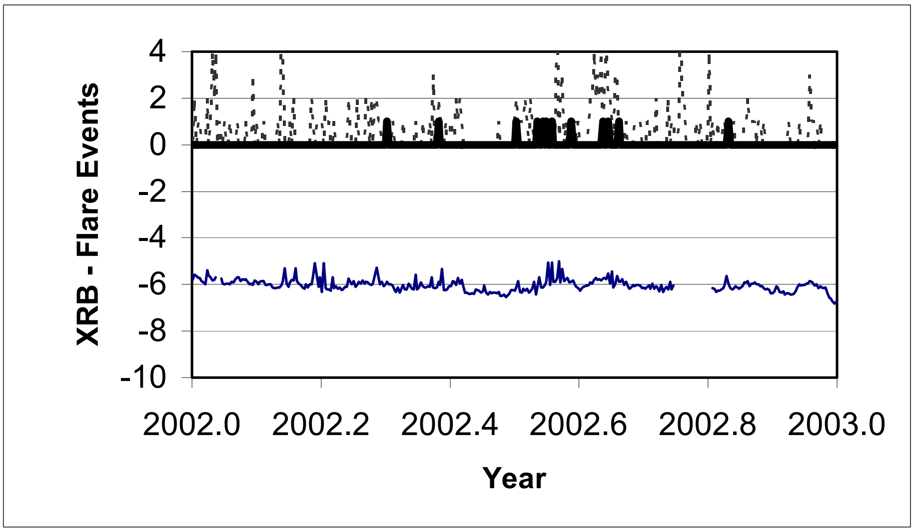
XRB - Flare Events
4
2
0
-2
-4
-6
-8
-10
1999.0
1999.2
1999.4
1999.6
1999.8
2000.0
Year



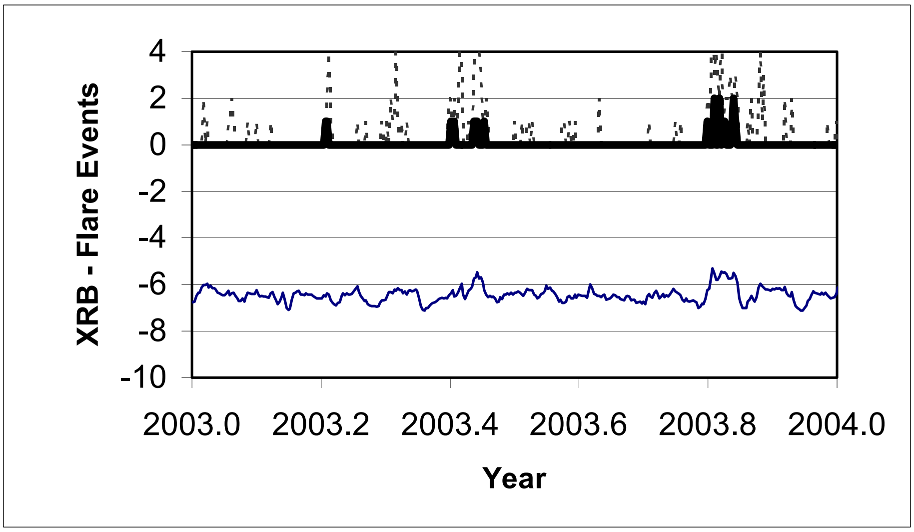
XRB - Flare Events
4
2
0
-2
-4
-6
-8
-10
2000.0
2000.2
2000.4
2000.6
2000.8
2001.0
Year



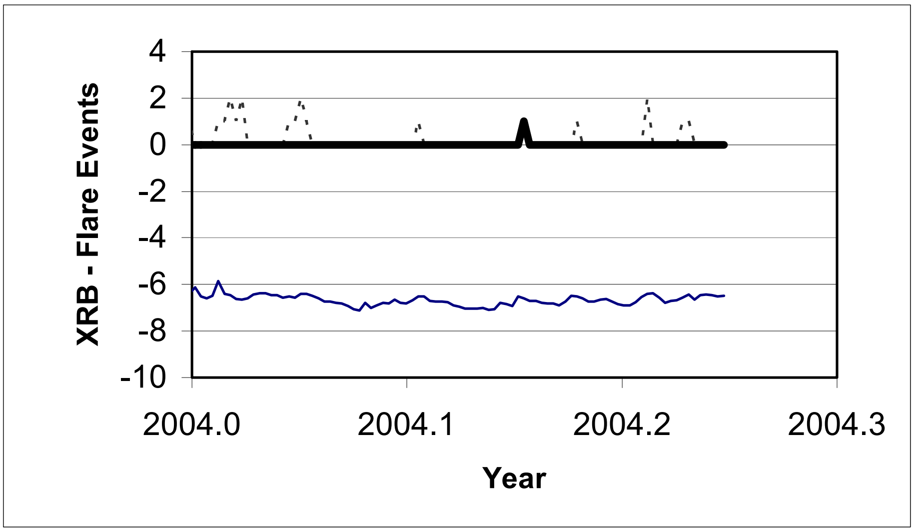
XRB - Flare Events
4
2
0
-2
-4
-6
-8
-10
2001.0
2001.2
2001.4
2001.6
2001.8
2002.0
Year



XRB - Flare Events
4
2
0
-2
-4
-6
-8
-10
2002.0
2002.2
2002.4
2002.6
2002.8
2003.0
Year

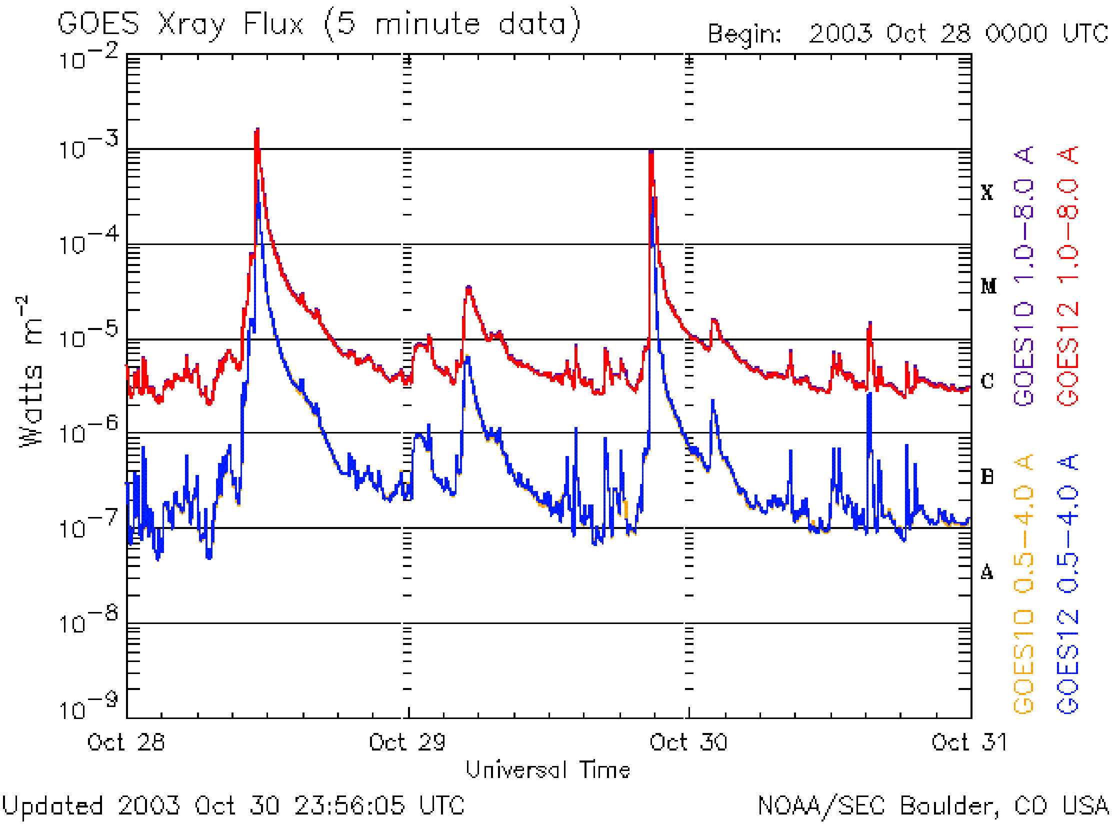


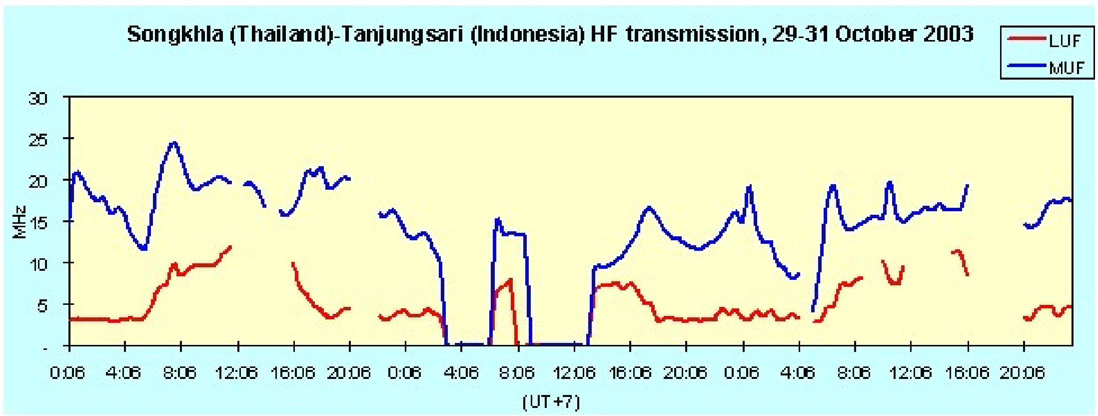
XRB - Flare Events
4
2
0
-2
-4
-6
-8
-10
2003.0
2003.2
2003.4
2003.6
2003.8
2004.0
Year



Concerning the impact, the effect on high frequency (HF) communication was also analyzed. It is known that blackout of HF may occur during major flare events. Space observation in Indonesia has shown that such effects may also be detected in equator regions. During major flare events in October and November 2003, a blackout of HF communication in ionosonde observation between Songkhla, Thailand and Tanjungsari, Indonesia was detected (Jiyo, 2003; see figures on the next page). It was also reported that the same effect was noticed in Australia and New Zealand during X10 flare on 29 October 2003 at about 20:00 UT[3] The effect was detected on the ionosonde at about 03:00 LT on 30 October 2003 (~20:00 UT 29 October 2003).

[3] (http://www.ips.gov.au/category/educational/space%20weather/space%20weather%20effects/oct-nov-03-activity.pdf).





5. Concluding remarks

Space-based data on astronomy, solar physics or solar-terrestrial physics are very helpful for developing countries that participate in space science research. The lack of observational facilities and the problem of clear night or light pollution could be overcome with such space-based data. Not only pure science, but also "down- to-earth" applications could be conducted. Accessible data from open on-line astrophysical data centres, including the virtual observatories, as well as abstract and full-text services, such as the Astrophysics Data System (ADS), are very useful. Due to low speed Internet connection, small size image format, numerical data and GIF plot are also useful.

Acknowledgement

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Jiyo (2003), Private Communication.
Kun, M. *The Astrophysical Journal Supplement Series*, 115. (1998): 59 – 89.

Status of the Cospas-Sarsat System

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Cospas-Sarsat Secretariat

Introduction

The International System for Search and Rescue (Cospas-Sarsat) is available to all countries on a non-discriminatory basis and is free of charge for the end-user in distress. There are at present 37 countries and organizations formally associated with Cospas-Sarsat.

Cospas-Sarsat assisted in the rescue of 1,414 persons in 366 search and rescue (SAR) incidents during 2003. The geographical distribution of all reported 406 MHz and 121.5 MHz SAR events that used Cospas-Sarsat data is shown in Figure 1. Of these events, 269 were maritime incidents (1,235 persons rescued). Further categorizing the maritime incidents, 56% involved the use of 406 MHz beacons and 44% involved the use of 121.5 MHz beacons.

Figure 1: Geographical distribution of all reported Cospas-Sarsat search and rescue events (2003)

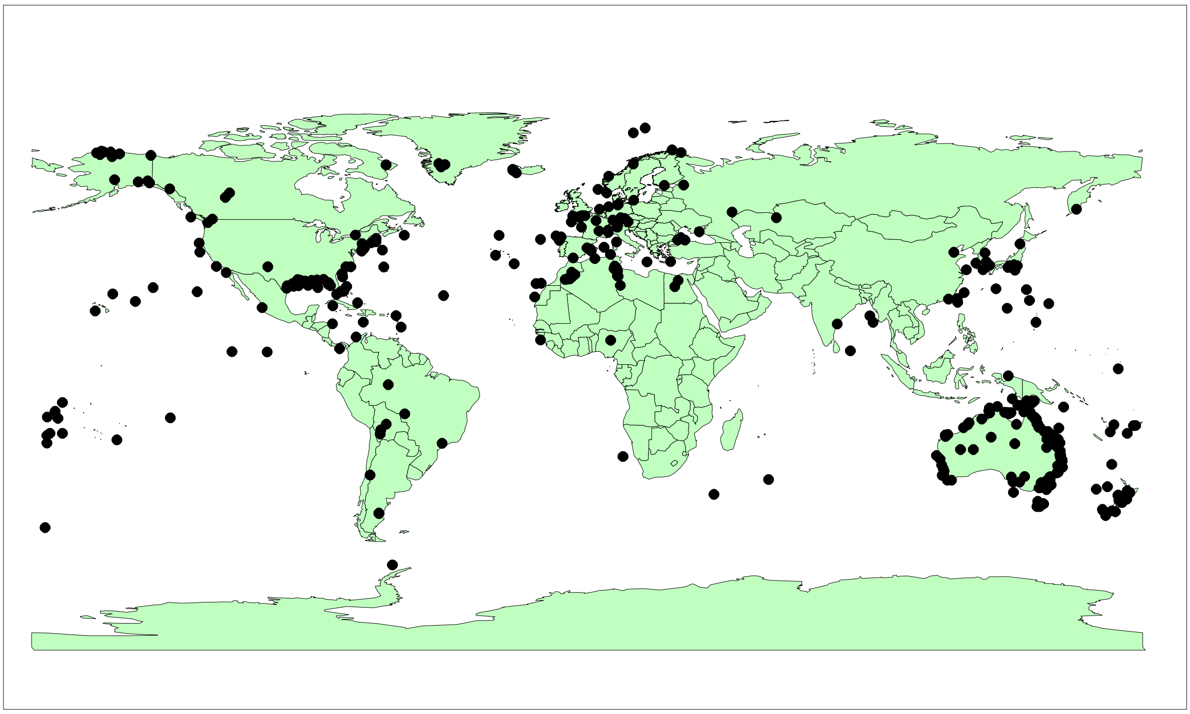


Figure 2 shows the evolution of use of the System since 1990. Since the beginning of its operation in September 1982 until the end of 2003, Cospas-Sarsat provided alerts that assisted in the rescue of 17,117 persons in distress in 4,851 SAR events.

Space Segment Status

As of 1 February 2004, the Cospas-Sarsat Space Segment was composed of seven satellites in polar orbit and four geostationary satellites plus two spares. The Space Segment status is summarized in Tables 1 and 3. The 406 MHz Geostationary Earth Orbit Search and Rescue

(GEOSAR) coverage is shown in Figure 3.Figure 2: SAR events and persons rescued with the assistance of Cospas-Sarsat.

Figure 2: Alert Data (January 1990 - December 2003)

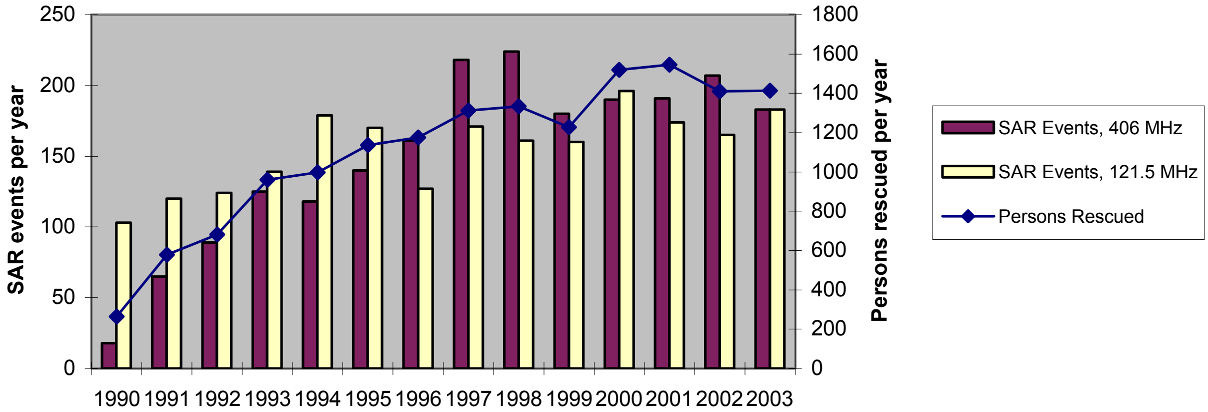
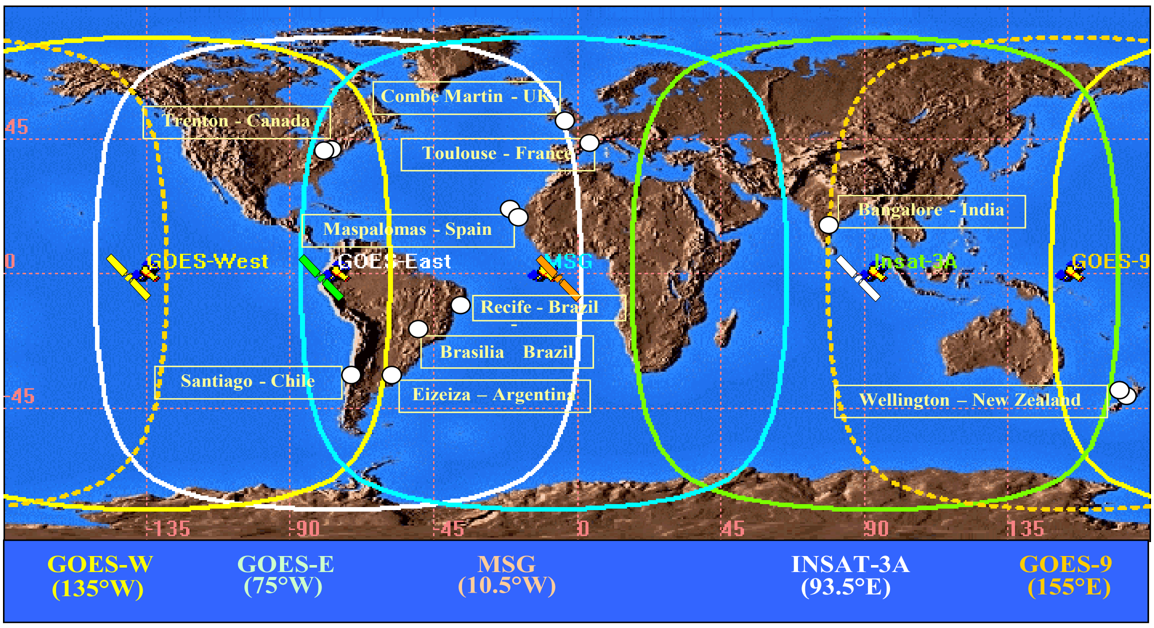


Table 1: Cospas-Sarsat LEOSAR Space Segment Status (February 2004)

Cospas-Sarsat Payloads in-Orbit	406 MHz SARP Global Mode	406 MHz SARP Local Mode	406 MHz SARR Only Local Coverage	121.5 MHz SARR Only Local Coverage	Date Launched
Cospas-4	(1)	(1)	NA	(1)	July 1989
Cospas-9	N	N	NA	O	June 2000
Cospas-10	N	N	NA	O	26 September 2002
Sarsat-6	N	N	O	O	December 1994
Sarsat-7	O	O	O	O	May 1998
Sarsat-8	O	O	O	O	September 2000
Sarsat-9	O	O	O	O	June 2002

<u>Notes</u>:
O - Operational
NA - Not applicable
SARP - SAR processor (provides global 406 MHz coverage)
SARR - SAR repeater (provides only local mode coverage)
N - Not operational
(1) - Not in continuous operation due to degraded battery, limited operation in the Southern hemisphere

Figure 3: Cospas-Sarsat GEOSAR Coverage and GEOLUTs (February 2004)



Ground Segment Status

As of 1 February 2004, the Cospas-Sarsat Ground Segment comprised 39 operational Low Earth Orbit Search and Rescue Local User Terminals (LEOLUTs), ten GEOSAR Local User Terminals (GEOLUTs) and 25 Mission Control Centres (MCCs) (see Tables 2 and 3). During 2003, one MCC in Thailand was commissioned into the System. Additional MCCs are under development in Nigeria and Viet Nam. The new GEOLUTs in Argentina, Canada, Chile, and the upgraded GEOLUT in Spain reached Full Operational Capability (FOC). Six LEOLUTs in Brazil, Nigeria, Thailand and Viet Nam are under development.

Table 2: Cospas-Sarsat LEOLUTs and MCCs Status (February 2004)

Participant	LEOLUT Name	LEOLUT Status	MCC Status	Participant	LEOLUT Name	LEOLUT Status	MCC Status
Algeria	Ouargla	O	O	New Zealand	Wellington	O	(1)
Argentina	Parana	O	O	Nigeria	Abuja	UD	UD
	Rio Grande	O					
				Norway	Tromsoe	O	O
Australia	Albany	O	O		Spitsbergen	O	
	Bundaberg	O					
				Pakistan	Lahore	O	UD
Brazil	Brasilia	UD	O				
	Manaus	UD		Peru	Callao	O	O
	Recife	UD					
				Russian Federation	Arkhangelsk	O	O
Canada	Churchill	O	O		Moscow	N*	
	Edmonton	O			Nakhodka	O	
	Goose Bay	O					
				Saudi Arabia	Jeddah	O	O
Chile	Easter Island	O	O				
	Punta Arenas	O		Singapore	Singapore	O	O
	Santiago	O					
				South Africa	Cape Town	O	O
China	Beijing	O	O				
				Spain	Maspalomas	O	O
France	Toulouse	O	O				
				Thailand	Bangkok	UD	O
Hong Kong, China	Hong Kong	O	O				
				UK	Combe Martin	O	O
India	Bangalore	O	O				
	Lucknow	O		USA	Alaska	O	O
					California	O	
Indonesia	Jakarta	O	O		Guam	O	
					Hawaii	O	
Italy	Bari	O	O		Florida	O	
					Texas	O	
ITDC	Keelung	O	O				
				Viet Nam	Haiphong	UD	UD
Japan	Yokohama	O	O				
Republic of Korea	Daejeon	O	O				

Notes: O - Operational
N - Not operational
UD - Under development
(1) - LEOLUT connected to the Australian MCC
* - Out of operation due to relocation

Table 3: Cospas-Sarsat GEOSAR System Status (February 2004)

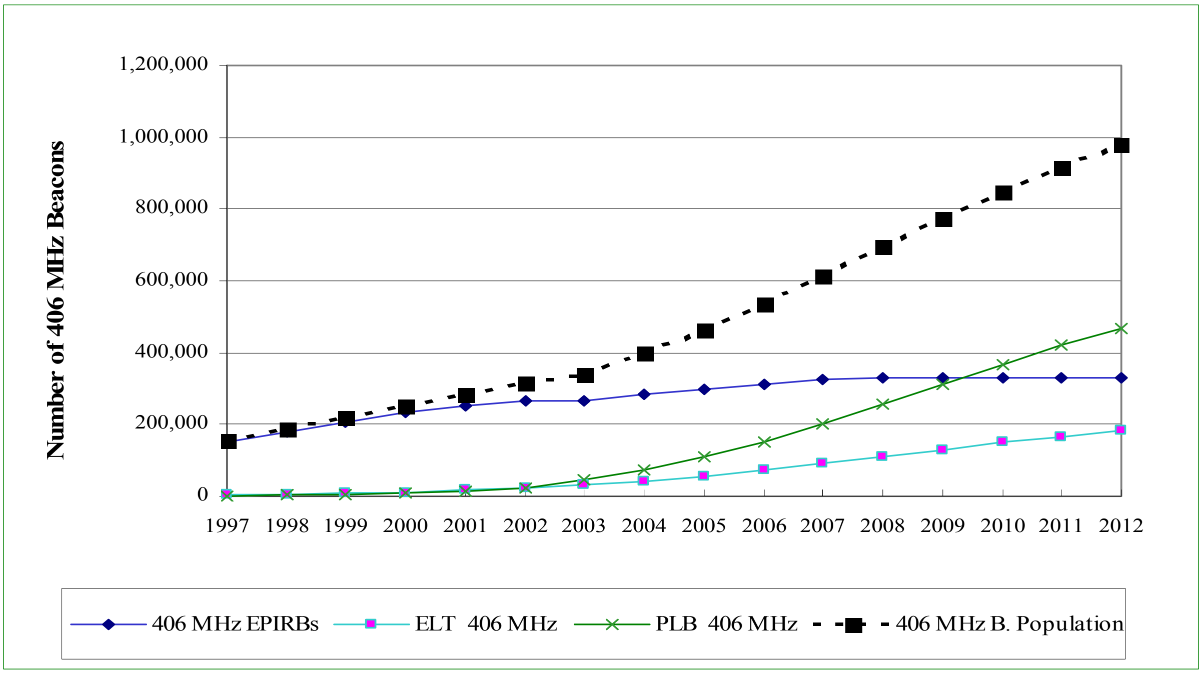
Satellite	Location	Status	GEOLUTs
GOES–W (USA)	135 ° W	In operation (GOES-10)	Trenton (Canada), Wellington (New Zealand)
GOES-E (USA)	75 ° W	In operation (GOES-12)	Ezeiza (Argentina), Brasilia, Recife (Brazil), Trenton (Canada), Santiago (Chile), Maspalomas (Spain), Combe Martin (UK)
GOES–9 (USA)*	155 ° E	In operation	Wellington (New Zealand)***
GOES–11 (USA)	105 ° W	In-orbit spare	
INSAT–3A (India)	93.5 ° E	In operation	Bangalore (India)
MSG-1 (EUMETSAT)**	10.5 ° W	In operation	Maspalomas (Spain)***, Toulouse (France)

Notes: * GOES-9 was moved to 155° East to support the operations of the Japanese Meteorological Agency.
** MSG-1 position will be moved to 3.5° W after completion of testing.
*** Under development.

Distress Beacons

It is estimated that over 341,000 distress beacons operating at 406 MHz and about 680,000 of the older generation 121.5 MHz beacons were in service at the beginning of 2004. The majority of 406 MHz beacons in service are maritime Emergency Position Indicating Radio Beacons (EPIRBs); however, the number of 406 MHz aviation Emergency Locator Transmitters (ELTs) and Personal Locator Beacons (PLBs) continues to increase rapidly. A forecast of the 406 MHz beacon population is shown in Figure 4.

Figure 4: Forecast of 406 MHz Beacon Population



A detailed list of 406 MHz beacon manufacturers and type-approved models is provided in the document Cospas-Sarsat System Data and is available from the Cospas-Sarsat web site (http://www.cospas-sarsat.org).

While earlier models of 406 MHz beacons were operating in the 406.025 MHz channel since 1 January 2002, the carrier frequency of all new models of operational 406 MHz beacons has been moved to 406.028 MHz. Beacon models type approved before 1 January 2002 may continue to be produced and operated at 406.025 MHz. At present, 10 models have been type approved for operation in the 406.028 MHz frequency channel. Additional channels will be opened as required to accommodate the growth of the 406 MHz beacon population.

Lower Cost 406 MHz Beacons

In deciding to terminate the satellite processing of 121.5 MHz signals from 1 February 2009, the Cospas-Sarsat Council recognized that some users might not voluntarily replace their 121.5 MHz beacons with 406 MHz models because of their higher price. Therefore, as part of the 121.5 MHz phase-out activities, Cospas-Sarsat has been actively investigating technologies and possible specification changes that would enable 406 MHz beacons to be produced at a lower cost, while maintaining the same operational performance.

During 2002 and 2003, Cospas-Sarsat conducted an extensive testing programme to verify the performance of LEOLUTs in the Cospas-Sarsat Ground Segment when processing beacon signals with revised frequency stability characteristics. In October 2004, the Cospas-Sarsat Council will decide if the 406 MHz beacon medium-term frequency stability specification would be changed to support the development of lower cost 406 MHz beacons.

Cospas-Sarsat False Alert Statistics

Table 4 shows statistics on 406 MHz beacon false alerts by category separately for EPIRBs, ELTs and PLBs, as presented by 21 participants who provided the complete breakdown, and an aggregate of 406 MHz false alerts for all beacon types, collected from 23 participant reports. Beacon mishandling remains by far the major cause of false alerts.

Table 4: Statistics on 406 MHz False Alerts by Category

Category of False Alert	EPIRBs		ELTs		PLBs		All Beacon Types	
	Number Reported (21 Reports)	%	Number Reported (21 Reports)	%	Number Reported (21 Reports)	%	Number Reported (23 Reports)	%
Beacon Mishandling	987	41.3 %	264	38.3 %	31	45.6 %	1,630	32.8 %
Beacon Malfunction	205	8.6 %	90	13.1 %	13	19.1 %	480	9.7 %
Mounting Failure	39	1.6 %	5	0.7 %	0	0 %	80	1.6 %
Environmental Conditions	202	8.5 %	5	0.7 %	1	1.5 %	216	4.3 %
Unknown	954	40.0 %	325	47.2 %	23	33.8 %	2,561	51.6 %
Total Number Reported	2,387	100 %	689	100 %	68	100 %	4,967	100 %

Based on the data provided by participants, Cospas-Sarsat calculates two false alert rates, identified for convenience as the “SAR false alert rate” and the “beacon false alert rate”. The SAR false alert rate, which characterises the impact of false alerts on SAR services, is the percentage of false alerts plus undetermined alerts over the total number of alerts transmitted to SAR authorities. Table 5 below shows the evolution of the false alert rate computed from a SAR response perspective for 406 MHz and 121.5 MHz beacons.

Note that a 98% false alert rate means that only one in every 50 alerts is a genuine distress situation, while a 95% rate indicates that one in every 20 alerts is genuine. Also, while the false alert rate for 121.5 MHz beacons remains stable, the increase in the 406 MHz rate is probably the result of the growth of the ELT population, which experiences a higher false alert rate.

Table 6 below shows the evolution of the 406 MHz beacon false alert rate (ratio of false alerts to the beacon population) from 1999 to 2003, by category of beacon and for all beacon types.

Table 5: SAR False Alert Rate

Beacon Type	121.5 MHz	406 MHz
1999	98.2 %	94.1 %
2000	98.3 %	94.2 %
2001	98.4 %	95.0 %
2002	98.2 %	94.6 %
2003	98.2 %	95.7 %

Table 6: 406 MHz Beacon False Alert Rate

Beacon Type	EPIRBs*	ELTs*	PLBs*	All Types**
1999	2.7%	15.1%	0%	4.0%
2000	2.6%	11.2%	0.8%	2.8%
2001	1.2%	9.8%	0.9%	2.8%
2002	3.0%	11.0%	1.2%	2.7%
2003	2.6%	8.9%	1.0%	2.9%

Notes: * No USA data 1999-2003, no New Zealand data 2002-2003
** Includes USA and New Zealand data; USA data for USMCC service area only

Interference in the 406.0 - 406.1 MHz Frequency Band

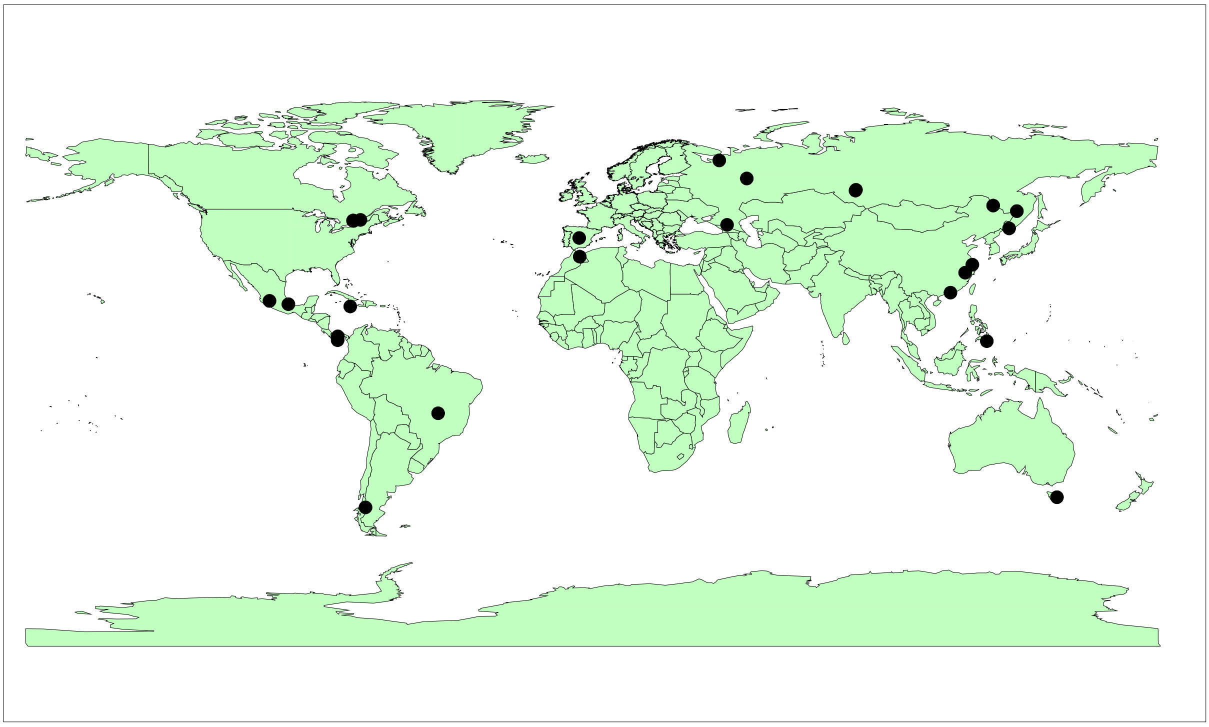
Table 7 shows the locations of 27 sources of 406 MHz interference in different areas of the world as observed in 2003. While the locations of the interference sources change annually, the number of interference sources has remained relatively constant over the past four years. Administrations should continue aggressive pursuit and elimination of all sources of 406 MHz interference. The locations of observed 406 MHz interference sources in 2003 are presented in Figure 5.

Table 7: 406 MHz Interference Sources (2003)

Country	Nearest City	Location
Australia	Orford	42-34 S / 147-52 E
Brazil	Pirenopolis	15-52 S / 048-50 W
Canada	Montreal	45-31 N / 073-32 W
	Ottawa (1)	45-24 N / 075-48 W
	Ottawa (2)	45-22 N / 075-54 W
	Ottawa (3)	45-17 N / 075-47 W
	Ottawa (4)	45-21 N / 075-46 W
Chile	Coyhaique	45-47 S / 071-55 W
China	Ch'uhsien	28-50 N / 118-42 E
	Hong Kong	22-28 N / 114-01 E
	Suchou	31-22 N / 120-57 E
Jamaica	Kingston	18-05 N / 076-46 W
Mexico	Carranza	18-48 N / 096-26 W
	Purepero	19-53 N / 102-25 W
Morocco	Taza	33-56 N / 003-49 W
Panama	Santa Catalina	08-34 N / 080-43 W
	Isla de Coiba	07-23 N / 080-46 W
Philippines	Davao	07-03 N / 125-34 E
Russian Federation	Arkhangelsk	64-32 N / 040-32 E
	Blagoveshchensk	50-11 N / 127-36 E
	Khabarovsk	48-23 N / 135-08 E
	Kirov	58-46 N / 049-16 E

Country	Nearest City	Location
	Nakhodka Novosibirsk (1) Novosibirsk (2) Pyatigorsk	42-56 N / 132-34 E 55-10 N / 083-58 E 54-56 N / 083-49 E 44-02 N / 043-02 E
Spain	Villaseca	39-53 N / 003-59 W

Figure 5: Locations of 406 MHz Interference Sources in 2003



International 406 MHz Beacon Registration Database

In 2001, Cospas-Sarsat started its investigations concerning the possible implementation of an International 406 MHz Beacon Registration Database (IBRD), which would provide significant benefits to SAR services and beacon owners, particularly when no established national database is available.

At its Thirty-third Session in October 2004, the Cospas-Sarsat Council is expected to select an Internet host site for initial operation of the IBRD. The IBRD should become available to administrations for use in registering beacons with their country code by early 2005. Administrations can chose to control the registration of beacons with their country code or can authorise users to register their beacons directly over the Internet. SAR services will be able to query the IBRD directly over the Internet.

Administrations interested in making use of the IBRD should provide the Cospas-Sarsat Secretariat with a national IBRD point of contact, who will be the recipient of passwords that will allow access to the database for uploading or querying registration information. For Cospas-Sarsat participants, the national IBRD point of contact will be the Cospas-Sarsat Programme Representative. For countries not associated with the Programme, Cospas-Sarsat will accept nomination of a national IBRD point of contact from either the International

Maritime Organization (IMO) or International Civil Aviation Organization (ICAO) official representative for that country.

Medium Earth Orbit SAR (MEOSAR) systems

Since 2002, the United States, the Russian Federation and the European Commission / European Space Agency (EC/ESA) have indicated their intentions to include 406 MHz SAR instruments on their respective constellations of global navigation satellites (GPS, GLONASS and Galileo) in Medium Earth Orbit (MEO). Cospas-Sarsat has been working closely with the United States, the Russian Federation and the EC/ESA to address compatibility issues, and to lay the foundation for the future integration of a 406 MHz MEOSAR system into Cospas-Sarsat.

406 MHz Ship Security Alert System Implementation

The 406 MHz Ship Security Alerting System (SSAS), approved for implementation by the Cospas-Sarsat Council, complies with IMO requirements for an SSAS as outlined in the International Convention for the Safety of Life at Sea (SOLAS) Chapter XI-2 “Special Measures to Enhance Maritime Security” and Resolutions MSC.136(76) and MSC.147(77) of the Maritime Safety Committee on performance standards for SSAS.

Administrations authorizing the use of Cospas-Sarsat 406 MHz SSAS should contact their supporting MCC to coordinate the appropriate data distribution procedures.

FROM FREEDOM TO ALPHA:
COOPERATION WITHIN THE INTERNATIONAL SPACE STATION

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Abstract

The politically driven process of construction within the space station from Freedom to Alpha provides an interesting example concerning the qualitative evolution from international collaboration to cooperation, the latter embodying more profound concepts like equitable roles, coordination instead of control, as well as trust and confidence among the partners. Economic issues, mainly space commercialization, also have influenced the relational profile within the consortium created to govern the space station programme. In the case of the International Space Station (ISS), learning from interaction has lasted a couple of decades due to institutional path dependence and international environment, even when the mission–oriented programme ISS goals are well defined.

1. Introduction

The International Space Station (ISS) is the most ambitious human space-flight project since the pioneer human missions to the moon. It aims to foster international cooperation and to provide a permanent human presence in outer space. More than a project, it is a programme drawing on the experience of 40 years of space flight, being built by 16 countries (United States of America, the Russian Federation, Japan, Canada, 11 European countries and Brazil).

The ISS architecture suggests a modular approach attempting to explain its construction, part by part, with connections to the different units under the partners' responsibilities and NASA's coordination under a new paradigm that privileges more equitable forms of cooperation in technological hardware contributions and decision-making dynamics. The physical and the political aspects that ISS exhibits are the result of a modular construction, piece-by-piece, negotiation by negotiation, during the last twenty years.

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[1] The research was conducted during the author's time as a Visiting Scholar at the Space Policy Institute/George Washington University – Washington, DC. The views presented in this article are entirely those of the author. The author expresses gratitude to J.M.Logsdon, M.Matt, J.Maia, D.H.da Silva Filho and A.Aquino for the suggestions. Financial support by CAPES (one year fellowship) and CNPq from Brazil are greatly acknowledged.
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It is the purpose of this article to describe briefly the steps of ISS construction, physically and politically, by outlining the main differences between space cooperation before and after ISS. The focus is on institutions, partners and U.S. domestic and foreign political issues.

2. Space station background

The role of institutions as well as individuals and the manner in which they interact constitute a landmark in the history of the space venture. Hence it is interesting to pinpoint some of the changes that occurred in the mid-1980s and consolidated in the 1990s to understand what have been the major factors that favoured the space station to become an international reality. But first of all, it is worth acknowledging very briefly the origins of the ISS to understand why it evolved into an international consortium.

One of the pioneer debates about the possibility of building a U.S. space station was held in 1960 in Los Angeles, USA, during a meeting sponsored by the National Aeronautics and Space Administration of the United States (NASA), the Rand Corporation and the Institute of Aeronautic Sciences. The follow-up to this meeting and other important occasions to discuss a space station since then came in 1961 when the President's decision in sending an astronaut to the moon and the start of the space race with the Soviets led to a slowdown in the space station project. There was not enough money to support both initiatives at the same time. Nevertheless, setting-up a platform in space, although not a governmental priority, continued to receive the attention of NASA's team engaged in designing and establishing the concept of a modular platform to be assembled in space. The fact that NASA elaborated technical plans to build a space station before political commitments were forthcoming indicates that this facility was a result of a political institution capitalizing on an emerging set of technical possibilities. NASA, anticipating political decisions, carried out studies and plans coordinated among the international partners, allies in Europe, Japan and Canada, under the patronage of the International Cooperation Working Group. Like a political candidate in an election campaign, soon after 1969 NASA incorporated new elements in its strategy in order to convince its supporters (congressional and industrial) to finance some of its programmes[2], namely, the space shuttle and the space station, as well as the continuation of the manned programme in order to survive politically, as perceived by NASA's administration according to Bruggeman[3].

Although the Nixon administration had manifested no interest in new investments in space, the President authorized the project to build the space shuttle in 1972. Nonetheless, the decision of setting up a space platform was postponed once again. Throughout the Apollo age, despite the fact that the transfer of technology to benefit society accounted as one of NASA's primary mandates, the Agency was not compelled to

[2] Logsdon JM. Space Politics and Policy: Facing the Future (pp.389-293) in Space Politics and Policy: An Evolutionary Perspective, Willy Z. Sadeh et al., Edited by Eligar Sadeh, 493 pages, Copyright 2002 by Kluwer Academic Publishers.

[3] Bruggeman D. NASA: a path dependent organization, in Technology in Society 24, 2002, pp.415-431.

demonstrate economic gains to justify its expenditures, enjoying rather a relative autonomy vis-à-vis other public policies.

The first phase of the U.S. space programme was developed under the 'Von Braun Paradigm', as coined by Pace[4] with the primacy of Cold War rules. The 'Von Braun Paradigm' looked so natural that it indeed continued to be updated even after 40 years. Over the years, recommendations for prospect space activities always contained similar ingredients, which means the building of progressively more complex capabilities using government-funded research. But it is not truly a coincidence. According to the paradigm theory, when one adopts a technological trajectory it lasts for some decades. [5]

As a matter of fact, the second age of the space history still continues under the 'Von Braun Paradigm', and this is one of the reasons it looks so logical. The construction of a space station as a platform to investigate life on Earth and celestial bodies in outer space as well as the possibility to build settlements on Mars to explore its natural resources, or to visit other planets in the solar system using the space station as a base (the goals of the mission-oriented ISS project) has followed up the 'golden age' of space exploration. Its use as a laboratory to carry on long-duration microgravity research is the new aspect. It is, nevertheless, only a rational use (and not a deviation from the initial trajectory) of the capability's utilization and an attempt to justify the costs of its construction and operation. The paradigm is essentially the same.

Nevertheless, the belief that a space station was a follow-up to the space shuttle project (Von Braun's paradigm) seemed natural in the early 1980s with the condition that the project could reach consensus and legitimacy within the realm of the U.S. President, Congress and the public. Consensus construction and articulation between the parties involved allowed for political support and rationales to brace what was deemed as technically feasible. Despite President Reagan's interest in space, he refused to endorse the space station at once, although, NASA set up the Space Station Task Force in May 1982. The Agency was in fact attempting to adjust itself to the new landscape, meaning programme approval even under conditions that placed long-term commitments at risk.[6]

Unlike the approach presented during the Apollo project when President Kennedy promoted his political agenda emphasizing space as the 'big picture', and political forces were marshalled for an abundantly funded technological effort, new perspectives had to deal with the ISS project and the related competing uses in an environment of limited financial and physical resources. Currently, space programmes need to be considered within the mainstream of public policy issues, and concerning the U.S. case, NASA must

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[4]Pace S. Merchants and Guardians in the New Millennium in Dual-Purpose Space Technologies: Opportunities and Challenges for U.S. Policymaking, Ed. by R. A. Williamson, Space Policy Institute-George Washington University, July 2001 pp. 191-201.

[5] Dosi G. Technological Paradigms and Technological Trajectories: A Suggested Interpretation of the Determinants and Directions of Technical Change, Research Policy 11, 1982, pp. 147-162.

[6] McCurdy HE. The decision to build the Space Station- Too weak a commitment? Space Policy, November 1988.

be placed necessarily in the mainstream, otherwise it would be compelled to occupy a marginal position in the concert of public policies.[7]

Big projects capable of capturing the collective imagination and of mobilizing society, such as the Apollo programme, became increasingly rare. Moreover, during the last couple of decades, the U.S. space programme accumulated some weakness and generated "(...) a substantial gap between the statements about the high importance of space to U.S. interests and both the current state of U.S. space capabilities and the priority given to the space sector by the country's leadership. The result is that a seemingly crucial national security, economic, public service and scientific capability rests on a very fragile foundation."[8]

3. Getting approval for the International Space Station

In 1983, officials of the U.S. Department of Defense made clear inside the Government their lack of interest in participating in the development of a space station. The military officials had argued that a human space station would have a marginal importance to national security operations. This statement gave the project its civilian façade and created the opportunity for advocates to proceed politically to allow NASA to invite international partners.

The debate about the space station went on in July 1983 during the symposium 'Space Station: Policy, Planning and Utilization' sponsored by The American Institute of Aeronautics and Astronautics and NASA to provide a forum for the space community to discuss the themes related to the design, technology and potential applications of the space station. James Beggs, then NASA's administrator, addressing the participants during the event, commented that the shuttle was a successful programme, however limited in extending the time of permanence in space for long–duration and long-endurance space flights. Beggs further explained: "For that purpose, NASA has always had in (...) mind the idea sooner or later we should have a space station. (…) It would give us the means to go beyond low Earth orbit and to do all the other things in a manned and unmanned dreamed of doing"[9] Beggs' statement made it clear that the basic justification to build a U.S. space station laid on competitive arguments aiming obviously to provide U.S. space leadership, but focusing on the economic and technological areas as well.

There were also concerns at that time about financing manned missions instead of robotic missions. Continuing a manned programme in the post-Apollo years was a NASA path-dependent organizational concept to follow its trajectory and to assure its survival politically. Then, space industry, NASA's ally, put pressure on the Government to speed up the decision. It came sooner when "Supportive White House officials arranged a meeting in August 1983 between President Ronald Reagan and the heads of eleven U.S.

[7] Logsdon JM. Space Politics and policy: Facing the Future, op. cit, Ref 2, p.

[8] Logsdon JM Reflections on Space as a Vital National Interest, Astropolitics, Vol.1, No.1, Spring 2003, pp. 77-87.

[9]Proceedings AIAA/NASA Symposium on the Space Station, July 1983. Copyright by AIAA.

corporations, including four executives from companies that could expect to win contracts to help build the space station, should one be approved. The executives told Reagan that America's aerospace business community needed a space station. Four months later, NASA officials presented their space station plans to President Reagan (…). One month later, Reagan directed NASA to begin work on the permanently occupied facility during his 1984 State of the Union address."[10] Domestic policy, lobbied by the aerospace industry and NASA's strategy, prevailed but compromised it from the long term to the short term.

President Reagan, whose administration assimilated space into its larger policy objectives and ideology of government, approved the construction of the space station named Freedom along with the 'space shields' Strategic Defense Initiative (SDI) as a joint effort to face the threats of the former Soviet Union. In doing so, Reagan exacerbated the intrinsic nature (the dual nexus) and the interplay of civil and military relations concerning space activities jointly with its commercial vision of space and therefore, albeit involuntarily, intensified the conflicts between distinct groups dealing with space policy. Using his presidential prerogative, Reagan ignored the advice of his Secretary of Defense, his Budget Director and his Chief Science Adviser, who opposed the space station project. Thus, the space station advocates won the battle to start the space station; a robust commitment to come to an end was, however, absent. Incremental space policies and amplification of constituency would sustain the space station project for the years to come as an international enterprise. "In this context, the Reagan administration's objectives for Space Station Freedom, (…) necessitated that it push American technological know-how so that the spin-off systems might also be used in SDI and that it serve as a rallying point for the nation's allies. As a result, from the outset the space station had to be a high priority international programme, for it was used to enhance the technical competence of the U.S. allies."[11] Other authors did not share this point of view, such as J. M. Logsdon[12], who did not see close connections between SDI and the space station. Whether the two projects were strategically bound or not, the fact is that as soon as President Reagan decided to approve the space station he headed some important meetings in Europe to convince resistant countries to engage in the programme, particularly the United Kingdom of Great Britain and Northern Ireland and France, for different reasons. Thus, since 1986 and as soon as the respective space agencies from Japan, Canada and Europe defined their contributions, they signed agreements with the United States covering an entire array of legal arrangements.

4. International collaboration before ISS

U.S. collaboration with some nations is recorded since the first years of the space programme. U.S.-European collaboration of some embryonic form has existed since 1959. In the ensuing years, this partnership expanded, still in a very limited way, however, in general through bilateral agreements with the clear supremacy of NASA, and with partners contributing with non-equitable roles. For many years, the European Space

[10] McCurdy HE. Bureaucracy and the Space Program, op cit. Ref 2, pp.105-128.
[11] Lanius RD. Historical Dimensions of the Space Age, op cit Ref. 2, pp.01-24.
[12] Personal communication, 2003.

Agency (ESA), as well as the individual space faring nations in Europe, although military allies, found it difficult to cooperate with the U.S., in part due to U.S. national defence policies, with the use of space by the U.S. for security purposes.

In fact, more systematic collaboration between the two partners dates back to the period of ESA's inception in the 1970s, when the U.S. proposed participation in its Space Shuttle Program through the provision of a laboratory that would be flown in the shuttle's cargo bay. ESA had actually been created to manage the European Ariane Space Programme. Under the leadership of France, Ariane was set up to enable Europe gain its autonomy from the U.S. in accessing space. (It proved finally to be a robust programme and a successful competitor in facing the U.S. space shuttles in commercial terms).

Collaboration was extended to a series of space labs flown since 1983 exploring areas such as microgravity and the atmosphere. These experiences were considered to have laid the basis for ESA to join the ISS project.[13] In this regard, Sadeh[14] remarked: "U.S.-European intergovernmental space relations have historically reflected power asymmetries in NASA's favor. (…) This pattern of cooperation eroded over time, as ESA became more capable due in large part to the cooperation with NASA that dependence first caused. As a result, U.S.-European space relations concerning ISS, for instance, exhibit more equitable forms of cooperation in technological hardware contributions and decision-making dynamics." McCurdy [15] also argued: "For domestic political reasons, (…) international partners could not participate in a U.S. Space Station on which the Defense Department was conducting weapons research. International partners also insisted upon the principle of mutual access, which would give them the right to use each facility on the Space Station regardless of who will build it."

Lack of trust, a characteristic of that period, made international collaboration a restricted activity, and from the U.S. prospective, it raised concerns involving basically the fact that the U.S. had the leadership in the transfer of technology (sensitive items); domestic versus foreign interests in space activities (civilian, military and security) and control along with management of the programme involving so many nations at the same time.

It is important to remind the reader that the space station had been conceived by the space visionaries, but under the auspices of the military-industrial-research complex, therefore under a 'pro-state' perspective, characterized by a professional technocracy that dominated the establishment of large-scale research and development programmes throughout the Cold War era, including the aerospace complex, with NASA enjoying a relative autonomy when compared to other public institutions and anticipating political decisions.

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[13] Georghiou L. Global Cooperation in Research, Research Policy 27, 1998 pp.611-626.
[14] Sadeh E. International Space Cooperation (p.285) op cit Ref. 2.
[15] McCurdy HE. The decision to build the Space Station- Too weak a commitment? op cit, Ref. 6.

5. Cooperation in the ISS era

International cooperation has indeed deeply influenced space policy in order to save the space station project. Becoming an international programme was the means to preserve the space station; otherwise it would have risked not being approved by the U.S. Congress. But enlarging participation to external members meant adapting the project to the new forms of international relations. This exercise had in fact begun since the early 1980s with some of the allies. The lesson was learned further: cooperation did not have the same meaning at all that it did during the Cold War era when the space programme operated largely outside the realm of 'normal politics' and there was, in fact, some degree of collaboration but little cooperation. Although the ISS cooperation was a crucial element in the U.S. foreign policy agenda, it also became a product of rational response to changed circumstances, even though this response had not been so direct due to the ISS peculiarities.

Much more than reducing costs and risks, cooperation has become an important tool to improve cross-fertilization of ideas, which represents one of the qualitative resulting gains when partners sum up their individual competence to accomplish common goals within collective projects like the ISS. However, caution ought to be taken to avoid considering cooperation as a panacea. In the case of the ISS programme, it could represent a short vision and a big mistake due to the political issues involved.

The rise of new players in the space marketplace led to a new pattern of relationship among individual firms, governments, private and public sectors, as well as the emergence of bilateral and multilateral strategic alliances and networks worldwide. Apparently without connection with the ISS as a civilian facility, compliance with the control regime of technology transfer of sensitive goods was in fact one prerequisite to make emergent space-faring nations, such as Brazil, be eligible as participants (not partners) in the programme.[16] The collapse of the Iron Curtain was also useful in this regard since it brought forth some important implications and explained partly the invitation to the Russian Federation to engage in the programme. Détente and the necessity to redesign the post-Cold War world required hard foreign politics.

6. Attempts to commercialize the space station

Although President Reagan had engaged himself in inviting and even convincing some of the partners in Europe to participate in the ISS programme, Reagan's administration lost interest in the programme soon after its announcement. As a consequence, the U.S. Congress had to back up its policy control. However, although Congress has been empowered to approve programmes and federal budgets, it "(…) is not generally able to force coherent long-term change, (…). Instead, legislative solutions tend to be across the board budget (...) percentage cuts or caps to which agencies adapt to

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[16] For a detailed discussion about Brazil-U.S. cooperation in the ISS programme, see Silva, D.H. da, Brazilian Participation in the International Space Program (ISS): Commitment or Bargain Struck? Accepted for publication in Space Policy, 2005.

as best as possible. This often means a continual downsizing of programs, but not a pruning out or elimination of a particular program. It also explains why NASA's programs, such as the ISS today, are often over budget and behind schedule."[17]

When the ISS received approval as an international project, the U.S. Government was emphasizing commercialization issues and private sector activities in domestic politics. Hence, it is more than a coincidence that in 1984 NASA presented its public policy statement 'NASA Commercial Space Policy', followed by NASA Task Force (Ride Report) entitled 'Leadership and America's Future in Space', in 1987, and then the presidential directive 'National Space Policy' in 1988; in 1990, President Bush approved the 'Commercial Space Launch Policy'.

Consistent with the Reagan Administration, and aiming at giving a commercial format to some of its projects, NASA, whose flexible matrix organizational structure involved the complex of domestic management, the body of outside contractors and the university research and development system, had established centres of commercialization within universities since the mid-1980s. The two earliest centres had been created to carry on research and development in new materials and biotechnology in view to develop new products to be commercialized; coincidentally the areas on which the ISS experiments were focused.

In 1989, President Bush fashioned his space policy in a unique intervention by proposing the Space Exploration Initiative (SEI) as a long-range continuing commitment including completion of the space station Freedom. As a follow-up, one finds two pillars sustaining President Clinton's Administration relating to the space station project: the Freedom's redesign and international cooperation within a whole space programme conceived as an economic investment. The financial resources to support microgravity research in the ISS programme was approved in the Fiscal Year 1991, when it was included in the budget as a recommendation from the Advisory Committee on the Future of the U.S. Space programme, emphasizing the space station as a laboratory for life sciences research. At that time, an important part of the scientific community also expressed its scepticism regarding the space station project. Scientists were attempting to avoid the dislocation of assets towards an uncertain and high-risk programme that would waste so much money and expose other ongoing projects. They argued that one could conduct similar scientific experiments in the existing laboratories on the ground. In so doing, the scientific community addressed its choice of saving public money with space-flights, human training, as well as in assembling the ISS blocks and keeping a permanent crew to operate and manoeuvre the platform to maintain its orbit. Only the researchers in the U.S. and abroad performing experiments related to growing protein crystal have manifested some positive expectations in using the special environment offered by the ISS capabilities. Nevertheless, NASA's administrator at that time attempted to get the financial and political support to continue the project, attempting to accomplish

[17] Johnson-Freese, J. Congress and Space Policy, op cit Ref 2, p.102.

commercialization goals. From then on, the politicization of the ISS programme became increasingly evident.[18]

Pursuing its goals towards space commercialization, the U.S. Government translated its willingness, through the Commercial Space Act of 1998, to encourage the development of a commercial space industry covering various aspects and with priority given to the ISS project. NASA promptly responded to this act by making efforts to commercialize ISS and setting up strategies for developing space commerce. Although the primary ISS objectives were to serve as a special laboratory to conduct scientific experiments and to serve as a platform for exploration of other celestial bodies; space business, controversial or not, including inside the ISS facilities, also became an important goal to achieve during the Clinton Administration.

In the case of the ISS programme, although the commercial impetus was separated from the exploratory and political objectives according to J. M. Logsdon[19], the pledge to transfer functions from the public to private sector motivating international partnership echoed everywhere. As a supporter of this position, McCurdy[20] expressed his point of view: “NASA executives spend a disproportionately large portion of their budget operating systems like STS and ISS and a variety of space telescopes, functions that people in the commercial space sector are increasingly capable of administering. Many experts believe that NASA ought to get out of the space operations business and concentrate on the research that leads to new technologies and the conduct of expeditions (human and robotic) where no business firms have gone before.” Commercialization initiatives had effectively little impact on the ISS project, mainly because of its nature as a mission driven project.

6. Freedom became Alpha

Aiming at commercialization goals and with the formal adherence of foreign partners, including historical enemies and rivals, the symbolic Freedom became the ISS after incorporating the Russian Federation as the last partner to join the consortium. In 1993, after the reformulation President Clinton imposed on the project, the space station project chosen then was the Alpha, with 75% of the initial conception concerning the hardware of the primary Freedom. The Russian Federation’s contribution was a hardware supplier redirecting important parts defined initially for the construction of the space station MIR 2. With the framework in place and the partners chosen, the station was then named the ‘International Space Station Alpha’.

As already mentioned, from the onset of the 1980s, U.S. domestic policies tried to encourage commercial activities in space. The threshold occurred with the enlargement of civilian space activities and during the Shuttle project when Congress authorized NASA, who had led the initiative, to open the programme to the private sector. But the transformation of ISS in business was not evident. Reflecting that behaviour, in the

[18] Beardsley T., Science in the Sky, Scientific American, June 1996.
[19] Personal communication, 2003.
[20] McCurdy HE. Bureaucracy and the Space Program, op cit Ref 2, p.127.

article entitled ‘The Branding of ISS’ [21], Jeffrey Manber commented that during a recent meeting with experts in the market for sponsorship and product branding, large companies’ representatives were eager to seize the opportunity to sponsor an ISS project but: “No one could pinpoint exactly what the ISS meant to the consumer.”

The current Intergovernmental Agreement (IGA) 1998, which furnishes a common legal regime to intellectual property rights, jurisdiction and control, as well as liability and customs, evolved in conformity with the progression from space station Freedom to International Space Station Alpha (ISS). In fact, there existed a limit to national jurisdiction over intellectual property as long as there was a margin between national and international laws. Actually, this question involves the concept of ‘freedom of choice’ related to an invention or discovery whose author is not a national of the flight element where the invention or discovery was made. Jurisdiction and control of elements are awarded based on sovereign principles in conformity with international space law. In fact, the Outer Space Treaty is applied to the ISS governing elements and nationals that are provided by a State, and the same rule is valid in intellectual property and criminal jurisdiction realms.[22]

Successive reviews to maintain the space station on track

During the last two decades, the idea of the ISS as a de facto long-term programme committed to an international level as a mission-oriented project has undergone many corrections due to the mutating environment that included its restructuring, reschedules, redesign of new transportation vehicles, negotiations involving political and budgetary modifications as well as the reduction of the number of the crew members, which is currently limited to three permanent astronauts aboard, and only two after the disaster with the space shuttle Columbia in February 2003.

The political choice that NASA had undertaken to have the project approved forced the Agency to adapt the long term to the short term, consequently having to negotiate each year the continuation of the project. Of course, update issues are necessary steps during the process of learning from interaction involving multilateral long-term enterprises, inasmuch the partners have to accomplish dramatic efforts in order to cope with the new agenda and especially to adapt their budgets to delays and the raise in terms of costs in the mid-1990s. In fact, for many people ISS is “(…) the ultimate ‘White Elephant’ Program. ISS comes up too often as a negative example of how things get done in government. As the program proceeds toward full operational status, questions are still being raised as to ‘why?’”[23]. Radford Byerly[24] pointed out that in the book entitled ‘Space Policy Alternatives’ published in 1992, which he co-authored jointly with Ronald Brunner and Roger Pielke, the following about the ISS was reported: “NASA and space

[21] SPACENEWS, January 13, 2003, p.15.
[22] Goldman NC. Analyses with some detail the international law concerning the agreements signed between NASA and the ISS partners. For this discussion see Space Law (pp 177-179) op cit Ref. 2.
[23] Johnson-Freeze J. Congress and Space Policy, op cit Ref 2 p.89.
[24] SPACENEWS January 21, 2003, p.15.

station supporters have been unable to 'build it right' and the opposition has been unable to 'not build it at all' and so the program continues".

ISS is not simply an assembly of blocks, system integration and engineering labour in the sky; it is rather a web of socioeconomic and political requirements that individuals, groups, institutions, governments, private and public actors, defending distinct interests, are compelled to articulate in order to set up in motion an effective network. That was one of the major reasons to justify the elaboration and implementation of six space station redesigns, the last of which was mandated by President Clinton in 1993[25] in part due to his policy of cooperation with the Russians in the space station, including the use of space station MIR during the steps of assembling the ISS site as well as to facilitate crew training, although redesigning and bringing the Russian Federation into the project ran as parallel but separated processes.

Space policy review often involves engineering details too. And since space programmes have been underway, someone has to be in charge of giving the political support to implement the decisions. As a matter of fact, the on-grounds ISS 'construction' is a dynamic political process**.** NASA officials, for example, carried on several legislative campaigns in order to save ISS. In 1993, the House of Representatives rejected an amendment by only one single vote to cancel the whole programme. The ISS has annually been subjected to efforts directed at policy change with varying intensity to terminate the programme or stretch it out to the brink of failure. In 1998, while the first elements of ISS were launched into orbit and in 2001 after ISS received the first astronaut crew, the programme was contested. First of all, there were problems involving Russian cooperation, invited as part of the U.S. foreign policy at the end of the Cold War. The Russian Federation struggled to build the Functional Generator Block (FGB) module, a unit essential to allow living and energy supply to ISS. The Russian Federation no longer occupies the comfortable place it used to share with the U.S. when they divided the World in two parts. This was one of the reasons that made the cooperation with the Russian Federation inside the ISS programme a case apart, or a very special case if compared to the other partners, such as the Europeans, Canadians and Japanese.

Yet NASA has received criticism for mismanagement that constituted a source of cost overruns on the station's congressional mandatory budget orientation. Congressional opposition raised over time as the technical issues placed obstacles to the development of the project generating scepticism concerning the success of the costly enterprise. [26] Although the first module was assembled, approximately 4,000 proposals had been submitted to NASA for station-based research. The spreading out of the conflict among sub-government political actors generated dynamic and adaptive space policy trends, which ultimately culminated in major redesigns in the ISS programme, even among the various NASA centres that had competed among themselves to see their projects approved, the last redesign to accommodate the Russian Federation, invited for geopolitical reasons, which became one additional problem for NASA to manage. After

[25] About this subject see Space Station Redesign Team Final Report to the Advisory Committee on the Redesign of the Space Station, June 1993.
[26] Johnson-Freeze, J. Congress and Space Policy, op. cit Ref 2 p. 83.

the signature of the various agreements and according to the new schedule, the first ISS module was finally launched into orbit in November 1998 and the first station crew began the missions two years later. The pioneer laboratory module was delivered in February 2001, allowing five labs and three robotic arms to be used for Space Station housekeeping and for conducting experiments.

7. Reaffirming the international commitments enforcing cooperation

Civil space officials in the U.S. have usually formulated international agreements with their counterparts in foreign countries in order to enlarge their base of support. An agreement with foreign governments aiming to cooperate in space activities, in theory, provides a layer of safeguard not afforded by an in-house enterprise. International agreements are more difficult to withdraw than domestic ones, due to foreign policy concerns and international compromises, engendering a tendency within the U.S. Congress to defer to the President. Moreover, international negotiations under the control of political agents, mainly Presidents and Prime Ministers and their representatives involving large and invaluable projects are more difficult to be manipulated, especially when geopolitical or foreign policies are at stake.

Space bureaucrats work within a complex milieu in which they maintain close relations with members of congressional committees who ultimately approve their programmes and allocate their funds. At the same time, space bureaucrats have attempted to construct alliances with their counterparts in other space agencies and communities, sometimes without success. Geopolitical issues have interfered strongly in the relations between space partners as argued by the participants in a workshop held in December 2000 at the George Washington University in Washington, D.C., about Russian affairs and U.S. foreign and national security policy. One of the participants stressed: "(…) the state of U.S.-Russian relations has deteriorated so much in the last few years that even a high-profile cooperative initiative such as the International Space Station is unlikely to produce significant improvement". Another participant to the same event pointed out that "(…) Russia has been more sensitive to and cooperative on nonproliferation issues than it would have been in the absence of the ISS project". Also a third participant has concluded: "(…) it was in part because of the ISS program that the Russian government agreed to abide by the MTCR (…)"[27].

It seems that the Russian space policy concerning international cooperation within ISS is focused at least on two aspects that are not incompatible with its interests. Such interests represent the needs to broaden space cooperation with other partners to continue as an important player in the area, while ISS, as a civilian programme devoted to scientific experiments and exploration helps to improve the U.S.-Russian relationship. The important issue (but out of the scope of this study) is what kind of cooperation is being established between the Russian Federation and these other partners, which involve nations once considered 'rogue' states by the U.S. administration. The U.S. invitation to Russian participation in the programme in the aftermath of the collapse of the Soviet

[27] Quoted pages 175 and 176 by J.M.Logsdon and J.R.Millar in US-Russian cooperation in human space flight: assessing the impacts, Space Policy 17 (2001) 171-178.

Union was a U.S. strategy to control the transfer of technology of sensitive goods, as well as to avoid scientific brain drain in that area.

During the United Nations Millennium Assembly, held in New York in September 2000, Presidents Clinton and Putin reaffirmed that ISS cooperation was an important item on their agenda. Once again, the U.S. and the Russian Federation reaffirmed their commitment to the ISS programme in June 2003 through a joint statement from the Presidents of both countries. The following words demonstrate their determination to cooperate: "We confirm our mutual aspiration to ensure the continued assembly and viability of the International Space Station as a world-class research facility, relying on our unprecedented experience of bilateral and multilateral interaction in space."[28].

8. Conclusion

The ISS programme is the largest peacetime scientific cooperative programme in history drawing on the resources and scientific expertise of 16 nations. The actors involved with the programme are nearly the same as those participating in the traditional international collaboration and industry-university interactions. Consequently, the network resulting from the scientific and technological interaction within the ISS is apparently familiar to many, but it is indeed different in character than any past ground-based collaborative initiative, as the present paper has attempted to demonstrate. It is really surprising nevertheless that an enterprise with so many qualifications has not reached consensus over time about its utility and necessity, and this for various reasons.

Almost 20 years have passed since the official beginning of the space station project. During this period, economic and mainly political issues have driven space policies to different paths. Space politics is now in the mainstream of public politics sharing priorities with agriculture, health and other areas. In that sense it has lost power. Cost reduction and technological projects with social impact became imperative with strategic alliances and cooperation as the instruments to accomplish those goals.

The commercialization impetus of space was part of the domestic politics since the beginning of the 1980s, but it is still viable only in a limited number of areas and the return of investments in space continue to be uncertain, risky and for the long term.

The delays in assembling the ISS blocs, successive design and schedule corrections over time, increasing costs as well as the financial difficulties of some members strain the relation with potential customers and financial backers and could potentially undermine the entire multinational cooperation and everything it represents to the public interests. The success of the commercialization of the international facility ultimately lies in finding the adequate mix of efforts between the private and government sectors, making a mission-oriented programme compatible with space business interests.

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[28] SPACENEWS, June 19, 2003.

The ISS programme is too symbolic, unique and the cornerstone in new trends to undertake international cooperation based upon trust between partners. It marks an evolution in terms of collaboration patterns emphasizing equitable roles and confidence among the partners. Positive factors combine to procure a potential international collaboration. The conditions today are distinct from those of the 1980s; collaboration has evolved into cooperation. The ISS experience is a crucial test as a prototype of a network developing in the new arena where foreign politics guide space policy. Since the end of the Cold War, civil space activity has an international component while economics provide the means to implement them, in the U.S. and elsewhere. In order for the entire project to be a successful enterprise, each member has the duty to contribute to it, since the positive results of cooperating within the ISS programme will deeply influence all future international collaborative ventures in science and technology with high implications for industry and society. Freedom to Alpha was a long journey to favour new relations either in the national or international spheres. The linkages inside the programme that were built over the last twenty years have exposed the new faces of cooperation where the learning process, trust and confidence fuelled the enterprise.

BAM EARTHQUAKE PREDICTION & SPACE TECHNOLOGY

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Introduction

The principal application of space technology to earthquake prediction has traditionally been in the form of measurements of ground motion. While this approach has contributed significantly to geophysical studies, it has not yet yielded an earthquake prediction method. An alternative approach that has recently shown great promise is satellite imaging of strange non-meteorological cloud formations and their correlation with earthquakes. Shou used such a cloud (see Fig. 1) to predict the earthquake of 26 December 2003 in Bam, Islamic Republic of Iran, to the public. Coarse and fine predictions were made public on the internet (@1) at 17:58 UTC, 25 December 2003. The fine prediction stated that there would be an earthquake of magnitude more than or equal to 5.5 within 60 days along a fault described in Fig. 1, while the coarse prediction allowed magnitude 5 and above, within 98 days. The Bam earthquake occurred precisely on the predicted fault, and its magnitude was within the predicted magnitude windows.

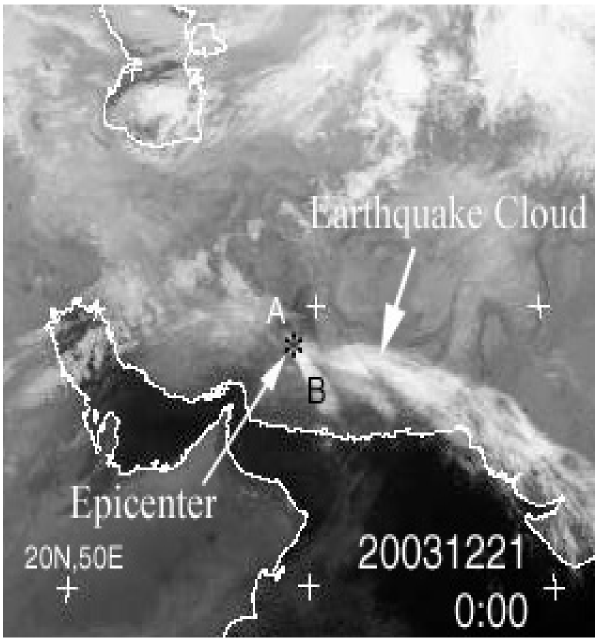

Figure 1: The Bam Earthquake Cloud
This image of IndoEx satellite (@2) shows an earthquake cloud emerging from fault AB on Dec. 21, 2003, marked by a white arrow, by which Shou predicted an earthquake of magnitude 5.5 or bigger in Fault AB within 60 days on Dec. 25, 2003 to the public (@1). On Dec. 26, an earthquake of magnitude 6.8 took place in Bam (28.99N, 58.29E), Iran (marked by *), exactly where the cloud had emerged.

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[*] 500E 63rd 19K, New York, NY 10021; **http://quake.exit.com**

The first known record of this kind of earthquake precursor is the Chronicle of Lon-De County, China, 381 years ago (recompiled in 1935): "It was sunny and warm; the sky was blue and clear. Suddenly, there appeared threads of black clouds spanning the sky like a long snake. The cloud stayed for a long time, so there would be an earthquake" (1). The predicted earthquake was the 7.0 magnitude Guyuan (36.5 N, 106.3 E), Ningxia province earthquake on 25 October 1622. It was the only big one in Western China (< 110 E) within 148 years from 26 July 1561 to 13 October 1709 (2), so this prediction is remarkable.

This method was recently revived in Japan and China. On the morning of 6 March 1978, Kagida, the former mayor of Nara city, Japan, predicted the 7.8 Kantow earthquake on 7 March by the clouds (1). He also proposed that the epicentre of an earthquake would be located in the mid-perpendicular plane of the clouds, which later proved to be incorrect. Following this successful prediction, there was a brief period of activity in the scientific communities in China and Japan. Three kinds of earthquake clouds: rope-shaped, rib-shaped (we denote it wave-shaped), and radiation-shaped, were announced. Unfortunately, the connection between clouds and earthquakes faded from view after 1985.

On the other hand, Shou made his first earthquake prediction in Hangzhou (30.25N, 120.17E), China, by a long line-shaped cloud with a tail pointing in the northwest direction on 20 June 1990. 18 hours later, a magnitude 7.7 earthquake struck Iran, and killed or injured 370,000 people. Because the earthquake was the only one bigger than 7 to the northwest of Hangzhou for 333 days from 31 May 1990 to 28 April 1991, Shou believed that there must be a strong relationship between the cloud and the earthquake. As long as the epicentre was not located by Kagida's law, but on where the cloud's tail pointed toward, he believed that the method of earthquake clouds should not have been abandoned.

Over the last 10 years, with the aid of satellite weather images available on the internet (@ 2-10), Shou has observed similar correlations in sufficient numbers to enable the development of a successful earthquake prediction method. He has used this method to generate 50 independent predictions certified by the United States Geological Survey (USGS), of which 36 were correct. This paper will describe a model to explain the correlations, a statistical analysis of the set of predictions and prospects for improving both the precision and reliability of the predictions.

Earthquake Cloud Model

Shou first proposed a model for the formation of earthquake clouds (2). When a huge rock is stressed by external forces, its weak parts break first and small earthquakes occur. For example, the Southern California earthquake data (@11) show that small shocks happened before and around all large hypocentres there (Table 1). The fact that a large earthquake produces a large gap suggests that small shocks generate small crevices, which reduce the cohesion of the rock. Next, underground water percolates into the crevices. Its expansion, contraction and chemistry further reduce the cohesion. Friction heats the water and eventually generates vapour at high temperature and pressure. The vapour erupts from an impending hypocentre to the surface by the crevices, and rises up. It forms a cloud while encountering cold air. This kind of cloud, whose vapour is from an impending hypocentre, is denoted an earthquake cloud. Anecdotal evidence for high temperature and high pressure vapour is plentiful (2-16), as is evidence for the clouds themselves. Fig. 2 shows damage to the ceiling of a structurally intact building due to the eruption of steam from underneath it during the 7.8 Tangshan earthquake on 28 July 1976 (17).

Table 1: All big earthquakes in Southern California and their foreshocks (1981~2004)

No.		Time			Mag.	Dep.	within 5 km		within 10 km	
	Date	UTC	Lat.	Lon.	ML	km	All	Over	All	Over
1	19871124	1:54	33.09	-115.79	6.2	10.81	25	4	138	10
2	19871124	13:15	33.02	-115.85	6.6	11.18	186	7	558	33
3	19920423	4:50	33.96	-116.32	6.1	12.33	321	3	1602	14
4	19920628	11:57	34.20	-116.44	7.3	0.97	166	146	520	461
5	19920628	15:05	34.20	-116.83	6.3	5.38	141	128	345	256
6	19940117	12:30	34.21	-118.54	6.7	18.40	9	2	79	5
7	19991016	9:46	34.59	-116.27	7.1	0.02	250	226	430	373
8	20031222	19:15	35.71	-121.10	6.5	7.01	12	1	37	7

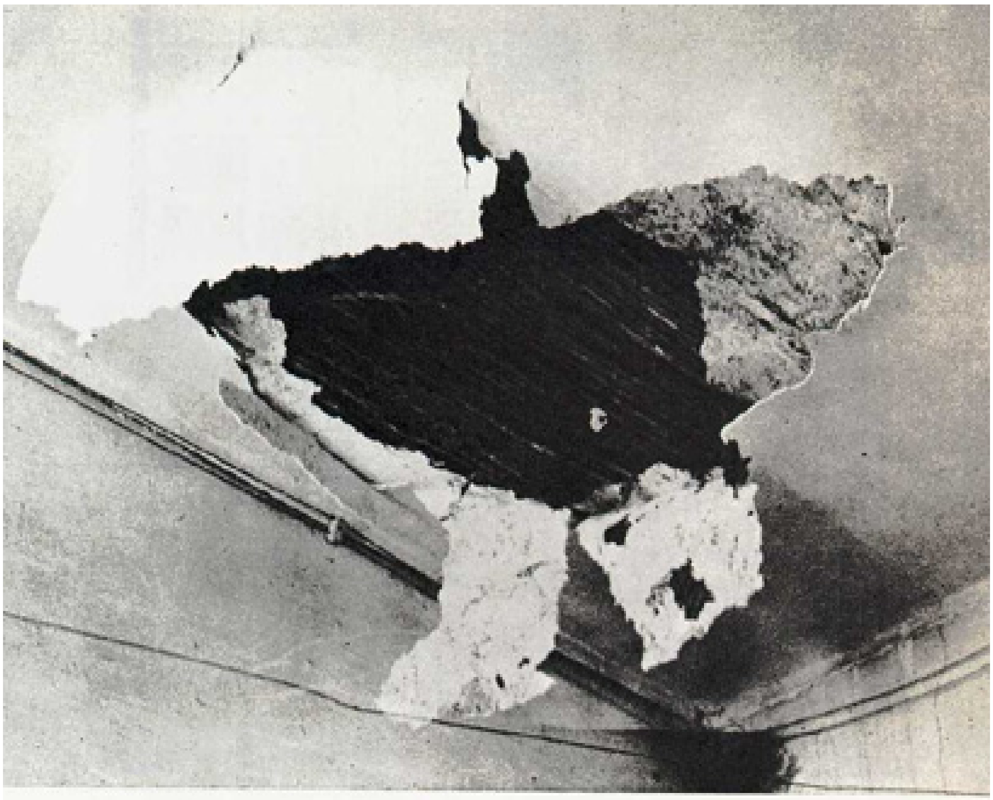
Note:

1. All above data are from the new catalogue of the Southern California Earthquake Data Center of the USGS since 1981(@11), covering a region of 32~37N. Column 8~9 and 10~11 indicate the number of foreshocks within 5 km and 10 km of an epicentre.

2. Lat. Latitude. Lon. Longitude. Mag. Magnitude. Dep. Depth.

3. ‘Over’ depicts the number of foreshocks, whose depths are more than or equal to a big earthquake. For example, earthquake No. 1 has 138 foreshocks within a distance of 10 km to the epicentre, in which 10 foreshocks are deeper than or equal to 10.81 km of the magnitude 6.2 hypocentre.

All large earthquakes have foreshocks around their hypocentres



7－17　丰南县宜庄公社一平房内喷沙冒水，冲破了房屋顶棚（10度区）。

In the area of intensity 10, sand boiling and water spouting occurred to a house in Yizhuang Commune in Fengnan County and spoiled the ceiling.

Figure 2: Tangshan earthquake damage
This photo shows damage in the roof of a building caused by steam erupting from the ground during the 1976 Tangshan earthquake (17). Photo ©China Academic Publishers

Not only does the vapour forming the cloud originate in the Earth, but its creation is intimately linked to the subsequent earthquake. There are two important pieces of evidence. First, the USGS performed an experiment at the Rangely Oil Field in Western Colorado, USA, in 1969 (18), in which water was injected into and pumped out of oil wells. Researchers found that there was a strong positive correlation between the quantity of water injected and seismic activity. Above a certain threshold of fluid pore pressure, seismic activity was observed to increase dramatically. Supporting this work are the results of laboratory studies of yield strength of saturated rock. As the rock is heated, the yield strength changes only gradually until a threshold temperature is reached. Past this threshold, the rock becomes dehydrated and its yield strength drops rapidly (Fig.10, (19)).

Our earthquake model demonstrates that the vapour in an earthquake cloud is precisely what escapes at the beginning of dehydration, i.e. when the yield strength begins to drop sharply. Once the yield strength has dropped sufficiently, the rock yields and an earthquake occurs. Thus, the atmospheric precursor we have discussed is directly linked to the generation of the earthquake itself.

An earthquake cloud can be distinguished from weather clouds by the following properties: a sudden appearance; a fixed source location (a fault); and a special shape such as a line, a snake, a few parallel lines, a bind of parallel waves, a feather, a radiation or a lantern pattern (2). These properties do not occur together in weather clouds (20). Fig. 3 reveals a time series of the Bam cloud that appeared suddenly from a fixed source (the Bam fault) at 2:00, 20 December 2003. The dense cloud formed in the midst of light clouds and expanded eastward while remaining connected to its source. Two animations can be viewed by accessing the following website: http://quake.exit.com/SHOU.zip.

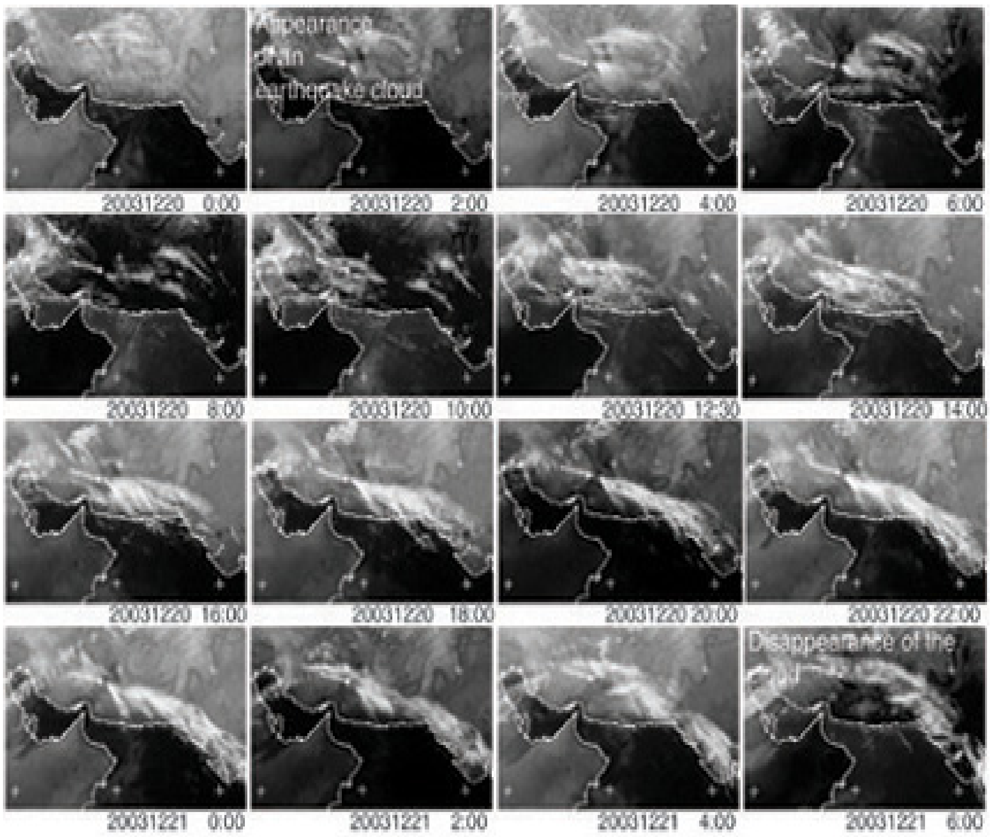


Figure 3: A Time Series of the Bam Earthquake Cloud
This series of IndoEx satellite images (@2) shows how the Bam earthquake cloud appeared suddenly, at 2:00 on 20 December 2003, expanded eastward from its point of emergence, then disappeared at 6:00 on 21 December.

Fig. 4 depicts several examples of suddenly appearing earthquake clouds over Southern California, including a cloud that appeared over Northridge direction nine days before the Northridge earthquake of 1994. Fig. 5, a photo looking towards Northern California on 3 August 1997 shows a cloudless line marked 4 that appeared in the midst of clouds and became a linear cloud six minutes after the photo was taken. Before the photo was taken, four cloudless lines had emerged rapidly, much faster than a jet trail. Two, marked 1 and 2, had entirely become line-shaped clouds and one, marked 3, had partially become a cloud for about three minutes. On 21 August 1997, a pair of magnitude 4.9 earthquakes occurred in Northern California. The width of these features and their rapid emergence strongly support the theory that hot vapour emerges rapidly from a line-shaped region of ground (i.e. a fault).

An earthquake cloud comes from an impending hypocentre, so its tail generally points toward or predicts an impending epicentre. The more mass an earthquake cloud has, the bigger the subsequent earthquake. By comparing the mass of an earthquake cloud with those of former clouds, whose relevant magnitudes are in an earthquake catalogue, the cloud can be used to predict its magnitude. Based on statistics from about 500 events, the longest delay from an earthquake cloud to its earthquake is 103 days, and their average is 30 days, so an earthquake cloud can predict the time. Therefore, an earthquake cloud can predict an earthquake. The Bam cloud is an excellent example to show that an earthquake cloud does in fact come from the Earth.

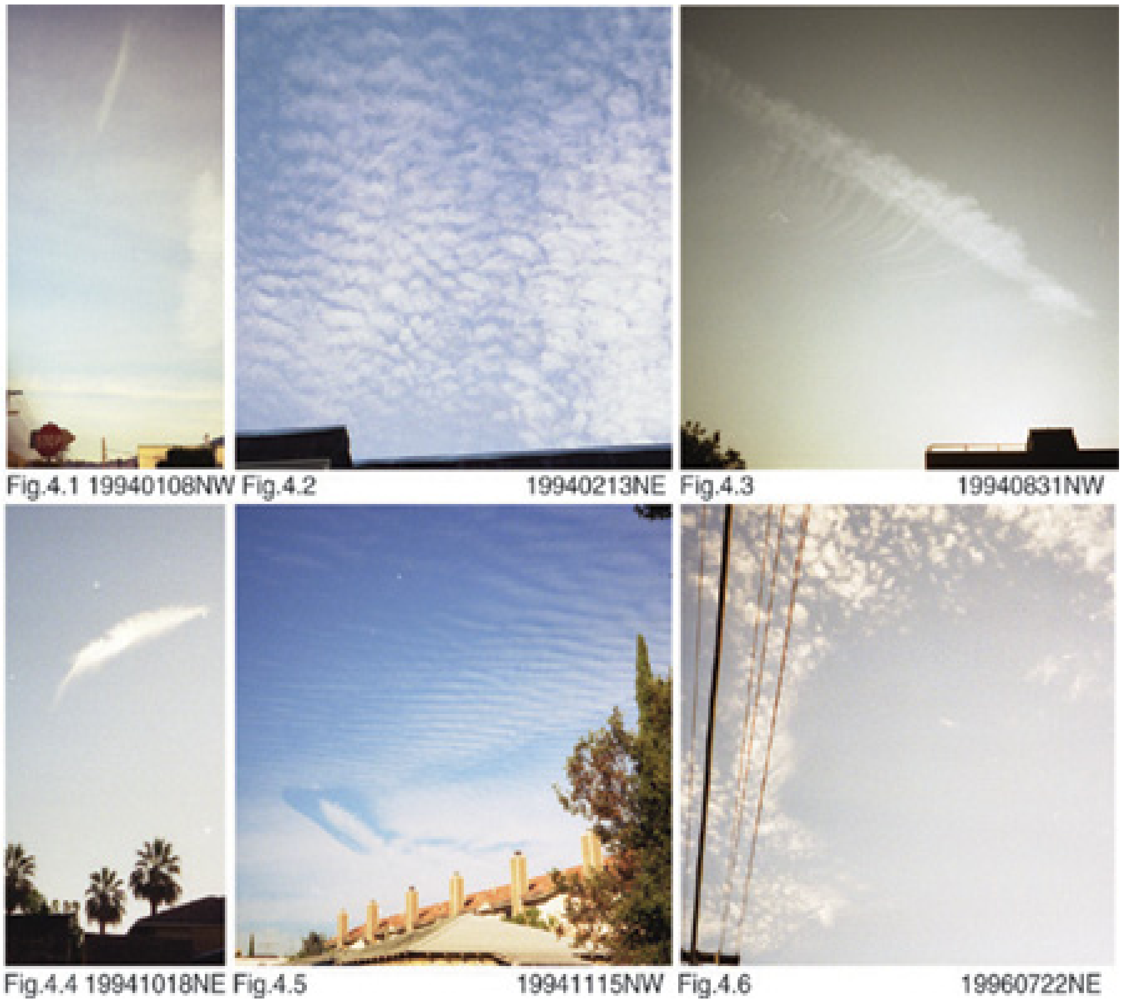


Figure 4: Various Shapes of Earthquake Clouds
This figure shows six different shapes of earthquake clouds, photographed by Shou from Pasadena (34.14 N, 118.14 W), California, USA. Under each photo are the date and the direction Shou took the photo. The line-shaped cloud in Fig. 4.1 appeared suddenly like a launching rocket northwest of Pasadena, and predicted the 6.7 Northridge earthquake at 34.21N, 118.53W, in the same direction, on 17 January 1994. The wave-shaped cloud in Fig. 4.2 was from northwest to northeast, and predicted the 5.3 Northridge earthquake on 20 March 1994. The line-shaped cloud in Fig. 4.3 appeared suddenly from northwest, and predicted the 7.1 Off Coast of Northern California earthquake at 40.40N, 125.68W on 1 September 1994. The feather-shaped cloud in Fig. 4.4 from northwest to northeast predicted the 6.3 Off Coast of Oregon earthquake at 43.51N, 127.42W on 27 October 1994. The lantern-shaped cloud in Fig.4.5 from northwest predicted the 6.8 Off Coast of Northern California earthquake at 40.55N, 125.53W on 19 February 1995. The radiation-pattern-shaped cloud in Fig. 4.6 rising up from northeast predicted the 4.4 Joshua Tree earthquake at 34.59N, 116.28W, in the same direction, on 14 August 1996. All these clouds were not described by meteorology (20), but both the wave-shaped and radiation-shaped clouds were denoted earthquake clouds by Chinese and Japanese scientists in 1979 (1).

Figure 5: Northern California earthquake clouds
This photo, taken by Shou from Pasadena, California, USA. toward the north on 3 August 1997, shows four lines that had appeared about 10 minutes, 8 minutes, 3 minutes, and less than 1 minute, respectively, before Shou took the photo. They all emerged suddenly looking like Line 4, straight, with an even width, and clear in the midst of clouds. They each took about six minutes to become a white, linear cloud. In the photo, Line 1 and 2 had already become clouds, and Line 3 had partially become a cloud, while Line 4 became a cloud six minutes after Shou took the photo. On 21 August, a pair of magnitude 4.9 earthquakes occurred at 38.5N, 118.5W, to the north of Pasadena, and were the only ones of magnitude more than or equal to 4 from 34N to 42N within 175 days from 7 May to 28 October 1997.

Geothermal Eruption

The Bam cloud was unusual since it emerged exactly from the epicentre. This was likely because its hot vapour condensed into a cloud immediately due to very cold surroundings at night during the winter. However, in many cases the vapour released at the epicentre does not immediately encounter atmospheric conditions suitable for condensation into a cloud. As a result, there is often a large distance between the first appearance of an earthquake cloud and its source. Since the cloud's travel time and direction are not well-known, this greatly reduces the precision, or specificity, of the prediction.

In the search for a solution to this problem, Shou identified another atmospheric phenomenon in images from weather satellites, which we denote geothermal eruption, or geoeruption. Geoeruption is qualitatively different from earthquake cloud although they have the same source, the impending epicentre. There are two key ingredients enabling the observer to distinguish this phenomenon in satellite weather images.

First, geoeruption emerges as a sudden localized atmospheric heating or disappearance of cloud, often occurring in the morning or evening, or covered by weather clouds or fog. In some cases the size of the emergence region is limited by the resolution of the public satellite images, about 10 km. Since the warm region often grows rapidly after its onset, to as large as 50x50 km^2 after one hour, variation in the size of the emergence is as likely to be an artifact of the finite frequency of the images, which varies from hourly to twice per day, as to have any physical significance. The second characteristic is the persistence of the warm region despite the presence of moving clouds overlapping or in the vicinity. Typically, the warm region expands while its source point remains warm through the duration, which can be up to several days, but is normally less than one day. We believe that the emergence region of this phenomenon precisely identifies the impending epicentre.

Fig. 6 shows a snapshot of several simultaneous geoeruptions in Taiwan on 30 January 2000. Over the next 46 days, one or more earthquakes of magnitude greater than 4 occurred at each of the pinpointed warm regions (Table 2).

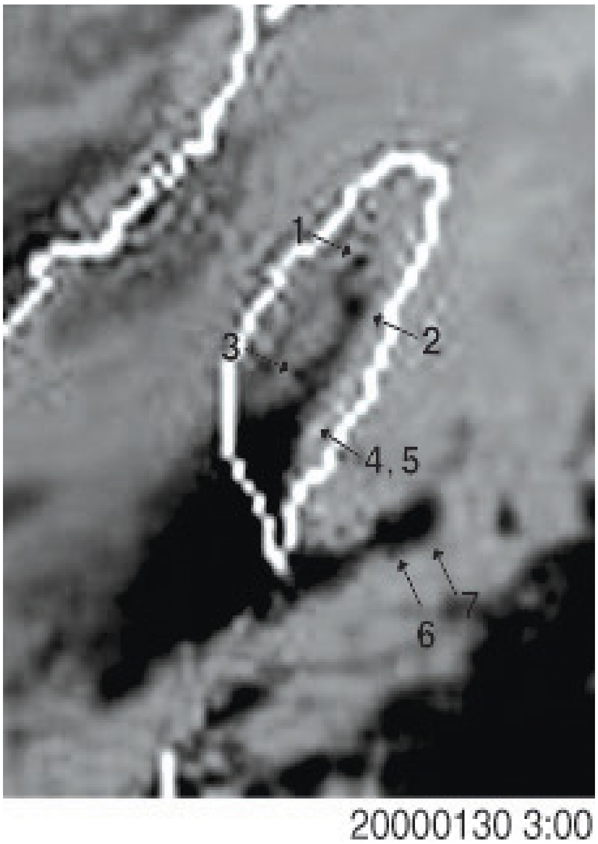


Figure 6: Taiwan geothermal eruption
This image from the Geostationary Meteorological Satellite (GMS) over Taiwan at 3:00 on 30 January 2000 was provided by Dundee University, UK (@2). Several dark spots, indicating warm regions, appear in the midst of cloud cover. Their unusual appearance leads us to believe that they were not weather-related, but instead were geothermal eruptions. Over the next 46 days, a series of eight earthquakes occurred at exactly the locations of the dark spots, as shown by the arrows. The earthquake data are shown in Table 2. The mottled appearance of parts of the image is a result of magnifying a small jpeg file.

Table 2: Taiwan Geoeruptions vs. Earthquakes

Geoeruptions					**Earthquakes**							
Date UTC	**Time**	**P**	**Lat.** N	**Lon.** E	**Date** UTC	**Time**	**Lat.** N	**Lon.** E	**Mag.** ML	mb	**Dep.** Km	**S**
20000130	3:00	1	24.4	121.1	000131	21:11	24.37	120.9	4.6		4.2	T
					000216	19:48	24.35	120.8	4.0		7.4	T
		2	24.0	121.2	000130	20:21	23.90	121.31	4.8	4.1	33	U
							23.90	121.31	4.8		7.5	T
		3	23.5	120.7	000131	2:57	23.51	120.48	4.2		4.7	T
		4	23.2	120.7	000215	21:33	23.35	120.93		5.3	33	U
							23.33	120.75	5.6		21.1	T
		5	23.2	120.7	000216	0:33	23.33	120.75	4.5		13.4	T
		6	22.2	121.4	000226	8:23	22.24	121.37		4.1	33	U
		7	22.2	121.8	000316	0:37	22.06	121.62	5.0	4.8	33	U

Note:

1. P: point number. Lat. latitude. Lon. longitude. Mag. magnitude. Dep. depth. S: source. U: the USGS (@12). T: the Central Weather Bureau of Taiwan (@16), received by Journalist Simin Li.

2. The latitudes and longitudes of the geoeruptions were calculated directly from the image, and have an uncertainty of 0.2°.

3. The average latitude and longitude absolute errors between the earthquake and the geoeruption point of origin are 0.09° and 0.15°, respectively.

Fig. 7 shows a time series of images taken over the Eastern Mediterranean from 8:00 23 February to 2:00 24 February 2000. Based on these images, Shou made a prediction certified by the USGS on 28 February 2000 that there would be a magnitude 5 or two magnitude 4 earthquakes within a coarse window of latitude 36.5N to 38.5N, longitude 36E to 39E (shown in the figure) and 50 days from 28 February to 18 April, and a fine window of latitude 37N to 37.8N, longitude 36.8E to 37.2E (too small to show) and 17 days from 25 March to 10 April. The prediction was correct, as two earthquakes occurred at point B, well within the coarse window, at the edge of the fine window, and coinciding with a bulge in the geoeruption. No other earthquakes of magnitude bigger than or equal to 4 have occurred in the fine area window in more than 14 years since the beginning of the database on 1 January 1990. Within the fine time window, the predicted pair were the only earthquakes bigger than or equal to 4 in the region 29~44N, 31~48E, a region 637 times larger than the predicted area. Earthquakes also occurred later at points A and C, again coinciding with geoeruption features (Table 3).

Similar to an earthquake cloud, a geoeruption can predict an earthquake for three reasons. First, its tail points toward the epicentre. Second, its mass indicates the magnitude. Third, its longest observed delay is 104 days, and the average is about 30 days.

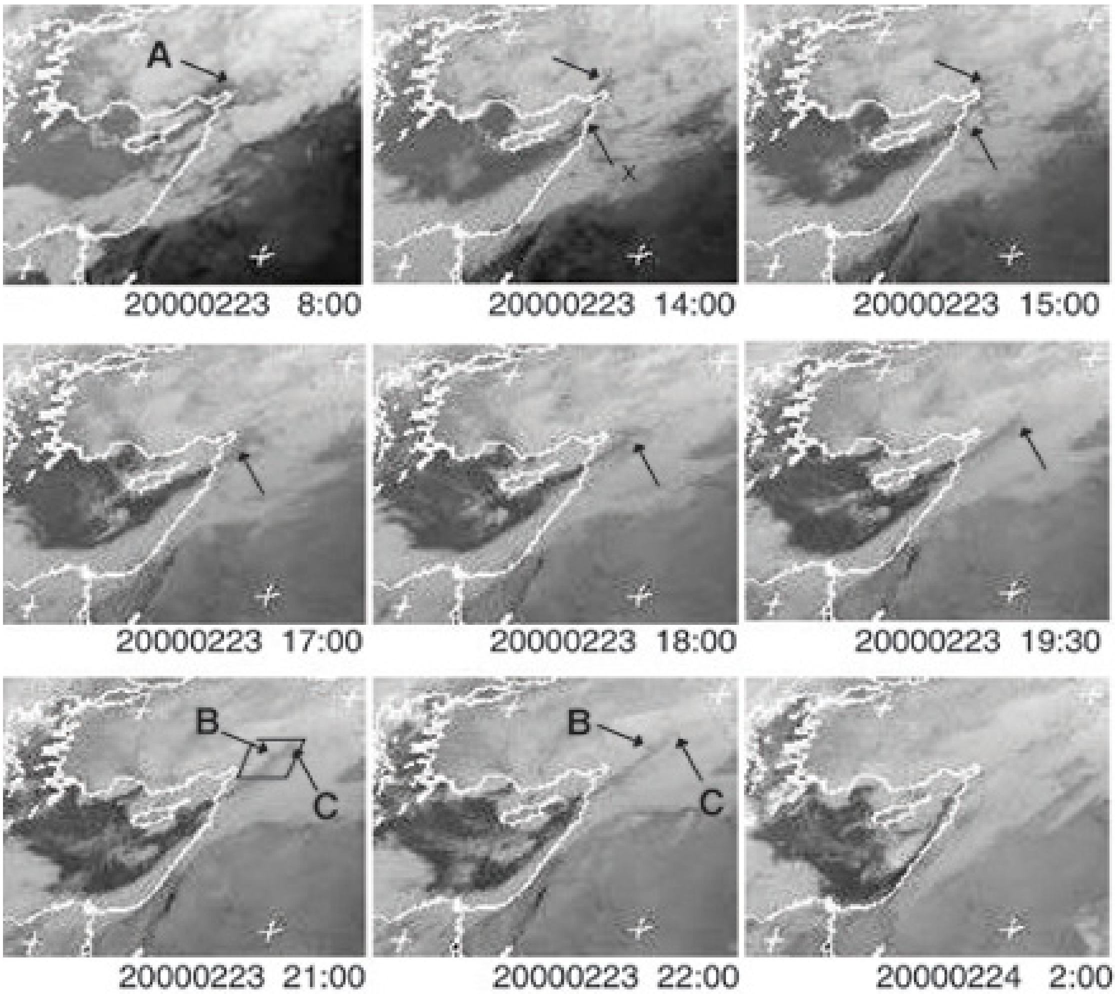


Figure 7: Turkey geothermal eruptions
This series of IndoEx satellite images of the Eastern Mediterranean was provided by Dundee University (@2). A geoeruption had occurred in Turkey at Point A (37N, 36.1E) at 8:00 on 23 February 2000, and disappeared at 15:00. Meanwhile, another warm spot appeared at Point X and grew toward the northeast. Two small bulges appeared at Points B (37.8N, 37.2E) and C (38.2N, 38E) at 21:00. Based on the feature at Point B, Shou predicted an earthquake to the USGS. The coarse area window of the prediction is shown by the black rectangle and the fine area window coincides with Point B. Two earthquakes of magnitude 4.2 and 4.4 occurred at Point B on 2 April 2000, 39 days later. Earthquakes also occurred at A on 12 May and C on 7 May. All data are shown in Table 3.

Table 3: Turkey Geoeruptions vs. Earthquakes

Geoeruptions					Earthquakes					
Date UTC	**Time**	**P**	**Lat.** N	**Lon.** E	**Date** UTC	**Time**	**Lat.** N	**Lon.** E	**Mag.** mb	**Dep.** Km
20000223	8:00	A	37.0	36.1	000512	3:01	37.05	36.08	4.7	10
	21:00	B	37.8	37.2	000402	11:41	37.57	37.19	4.2	9
					000402	17:26	37.65	37.23	4.4	9
	22:00	C	38.2	38.0	000507	9:08	38.18	38.75	4.2	1.6
					000507	23:10	38.16	38.78	4.5	5.4

Note: P. Point of a geoeruption in Fig. 7. Lat. Latitude. Lon. Longitude. Mag. Magnitude. Dep. Depth. The earthquake data are from the USGS (@12), and the average latitude and longitude absolute errors between the earthquake data and the geoeruption data are 0.10° and 0.32°, respectively.

Statistical Significance

In order to objectively evaluate the significance of an earthquake prediction, Shou proposed a probability calculation to simulate a random time guess. From a comprehensive earthquake database, select all earthquakes whose epicentres are within the predicted area and whose sizes are within the predicted magnitude range. Consider all time windows of the same time span as the prediction, using 1-day resolution. If a time window guess contains one or more of those selected earthquakes, it is a hit. Let A be the number of all hits, and B be the number of all time windows, then the probability for a random guess with the same time span to be correct is A/B (2). Table 4 selects all earthquakes of magnitude more than or equal to 5 in Fault AB from the World Earthquake Catalog of the USGS (@12) from 1 January 1990 to 20 December 2003, a total of 5102 days. The coarse time span of Shou's Bam prediction is 98 days, so B= 5102-98+1=5005. The table reveals A=98, so the probability is A/B=1.96% for the coarse prediction. For the fine prediction, there was no earthquake in the database, so its probability is close to 0. Therefore, the Bam earthquake prediction shows that earthquakes can be predicted in practice.

Table 4: the probability of the Bam earthquake prediction

	Latitude(N)	Longitude(E)	Magnitude	Coarse hits	Fine hits
19900101					
19980610	28.27	58.54	5.4	98	0
20031220					
Sum				98	0
Probability				98/5005	0/5043

Note: The period from 1 January 1990 to 20 December 2003 contains 5102 days. For the coarse prediction, it has 5102-98+1 = 5005 different time windows, whose spans are as the same as the predicted span, 98 days, such as (19900101~19900408), (19900102~19900409), etc. The database lists only one magnitude 5.4 earthquake in the coarse prediction area window. A total of 98 time windows, those beginning from 5 March to 10 June 1998 include the magnitude 5.4, so A=98 and its probability is 98/5005, or 1.96%. The database lists no earthquakes of magnitude 5.5 or greater in the fine prediction area window. Out of 5043 time windows of length 60 days, there are no hits, so the fine prediction probability is negligibly small (less than ~1/5000).

Based on observations of earthquake clouds and geoeruptions, both visible and infrared satellite images, Shou submitted 50 earthquake predictions between 1994 and 2001 to be certified by the USGS. Table 5 exhibits all of them, and their subsequent earthquakes, as reported in USGS databases. Assuming all earthquake data is without error, so called "Peer on", 34 predictions or 68% of them are correct in time, location and magnitude. They are called "hits", while the others are called "misses".

To evaluate the statistics, we adopt an unpublished method by Jones (@13) and Jones (@14) to evaluate a set of independent predictions. If a prediction has a probability **p**, it is assigned a positive score –ln **p** when it is a hit, or a negative score ln (1-**p**) when a miss (21). For a set of predictions, the normalized score S is the total score (sum of the individual scores) divided by the standard deviation of the total score. The distribution of S can be approximated as a normal distribution and thus the probability for a random guesser to equal or exceed the score is evaluated from the normal distribution (22) or (@15). For Shou's 50 certified predictions, the total score is 3.84, giving a chance of only 0.00062, or 1 in 16,000 for a random guesser. We also performed a direct computer simulation of the random guesser, which gave a chance of 0.00018, or 1 in 5,000 to achieve 34 or more correct predictions out of 50, given the calculated probabilities for individual predictions. This clear statistical significance validates the prediction method.

Table 5: Shou's 50 Earthquake Predictions reported to the USGS

No.	Predictions				Earthquakes					Prob.	Hit	Score	Var.
	Date	Time (LT)	Location	M	Date	Time	Lat.	Lon.	M	(%)			
1	940213	0213~0310	Around Pas.	4~5.5	225	12:59	34.36	-118.48	4.1	13.8	1	1.84	0.54
2	940330	0330~0424	Cal.	5~7	406	19:01	34.19	-117.1	5	27.1	1	1.18	0.52
3	940423	0423~0518	N Mex., S Cal.	>=4	512	0:22	25.07	-109.28	5.6	73.1	1	0.44	0.52
4	940603	0603~0628	S Cal.	3.7~5.5	615	5:59	34.31	-118.4	4.2	79.6	1	0.37	0.54
5	940910	0910~0925	20~50, 0~75	>=6	1025	0:54	36.36	70.96	6.2	20.0	0	-0.37	0.54
6	940916	0916~1011	Japan ~ Ale. < 500km	>=5	1004	13:22	43.77	147.32	8.3	99.9	1	0.01	0.05
7	941018	1018~1112	USA	>=5	1027	17:45	43.52	-127.43	6.3	48.1	1	0.72	0.48
8	950307	0307~0401	Mex., S Cal.	>=4	326	14:32	31.26	-114.35	4.2	100.0	1	0.00	0.00
9	950630	0630~0720	S Cal.	>=5	630	11:58	24.69	-110.23	6.2	8.9	0	-0.22	0.51
10	951011	1011~1105	Cal.	>=5	1021	2:39	16.84	-93.47	7.2	27.1	0	-0.44	0.52
11	960510	0510~0530	S Cal.	3.7~5.3	521	20:50	37.36	-121.72	4.8	31.6	0	-0.48	0.51
12	961025	1025~1119	S Cal.	>=4.5	1127	20:17	36.08	-117.65	5.3	28.5	0	-0.45	0.52
13	961125	1125~1220	Mex. ~ Peru	>=6	1231	12:41	15.83	-92.97	6.4	44.8	0	-0.63	0.48
14	961204	1204~1229	S Cal., N Mex. >30N	4~5.3	1217	4:03	36.08	-117.65	4	48.0	1	0.72	0.48
15	961206	1206~0105	Mex.	>=4.5	1208	23:52	14.99	-94.02	5	98.1	1	0.08	0.30
16	970306	0306~0405	N China >35N	>=6	405	23:46	39.51	76.87	5.9				
		0405 *20:36*			406	4:36	39.54	77	6	12.8	1	1.91	0.54
17	970424	0424~0610	S Cal.	>=4	426	10:37	34.37	-118.67	5.1	79.4	1	0.37	0.54
					427	11:09	34.38	-118.65	4.9				
18	970427	0427~0611	S Cal.	3.7~5.3	506	19:12	35.45	-118.43	4.5	93.7	1	0.18	0.47
19	970508	0508~0608	S Cal.	4~5.3	524	4:36	35.8	-117.64	4	63.4	1	0.53	0.50
20	970528	0528~0712	Turkey & Med. >=15E	>=5.5	630	21:48	36.63	31.41	4.5	35.6	0	-0.52	0.50
21	970718	0719~0809	S Cal.	>=4	726	3:14	33.4	-116.35	4.8	50.2	1	0.69	0.48
22	970804	0804~0828	S Cal.	>=4	821	16:11	38.57	-118.5	4.9	34.1	0	-0.51	0.50
						16:36	38.56	-118.49	4.8				
23	980105	0105~0218	25~41, 53~105	>=6	204	14:33	37.07	70.09	6.1	44.1	1	0.78	0.48

No.	Predictions Date	Time (LT)	Location	M	Earthquakes Date	Time	Lat.	Lon.	M	Prob. (%)	Hit	Score	Var.
24	980106	0106~0220	Mex.	>=5	203	3:02	15.88	-96.3	6.4	79.5	1	0.37	0.54
25	980309	0309~0423	15~30, <-150	>=4	507	23:15	19.22	-155.51	4.3	31.7	0	-0.49	0.51
26	980406	0406~0522	Mex., Cal., <34N	>=4.5	425	11:19	17.68	-94.19	5.2	99.3	1	0.03	0.17
27	980724	0724~0902	34~39, -119~-117	4~5.5	801	6:01	37.58	-118.78	4.4	54.9	1	0.63	0.48
28	981123	1123~0109	Cal. <39N	>=4.5	1212	1:41	37.51	-116.29	4.5	72.3	1	0.45	0.52
29	981228	1228~0213	33~39, -120~-116	4.2~5.4	125	18:52	36.81	-116.04	4.2	69.9	1	0.47	0.51
30	990222	0222~0408	20~38, 50~100	>=5.5	304	5:38	28.34	57.19	6.6	61.8	1	0.55	0.49
31	990402	0402~0520	24~34, -118~-108	4~5.2	428	19:08	30.3	-115.54	4.5	77.6	1	0.39	0.53
						19:34	30.25	-115.61	4.4				
32	990412	0412~0529	34~39, <-116	>=4	514	7:54	34.06	-116.37	4.9	83.1	1	0.33	0.54
33	990505	0505~0621	27~33, -117~-113	>=4	601	15:18	32.37	-115.24	5.1	40.0	1	0.86	0.49
34	990517	0517~0704	Mex. <29N	>=5	615	20:42	18.39	-97.44	7	79.5	1	0.37	0.54
35	990609	0609~0725	35~39, -120~-116	4~5.3	711	18:20	35.73	-118.48	4.6	61.9	1	0.55	0.49
36	990726	0726~0910	36~42, 113~117	>=5	817	10:41	29.41	105.61	4.8	4.7	0	-0.15	0.43
37	991028	1028~1214	30~33, -117~-115	>=4.3	1114	14:20	34.84	-116.41	4.5	15.7	0	-0.32	0.54
38	991227	1227~0210	Indian Ocean >20S	>=7	209	18:40	-27.62	65.72	5	0.0	0	0.00	0.00
					209	18:40	-27.69	65.71	5				
					210	14:18	-27.58	65.73	5.7				
					210	14:18	-27.66	65.68	5.7				
					210	23:00	-27.58	65.78	5.5				
					210	23:00	-27.63	65.76	5.6				
39	228	0228~0413	31~35, -116.5~-115	>=4.5	409	10:48	32.69	-115.39	4.3	21.6	0	-0.38	0.53
40	705	0705~0821	Japan <34, <142.5	>=6	730	12:25	33.9	139.38	6.5	32.2	1	1.03	0.51
41	10321	0321~0505	Cal. >38N	>=4	322	21:22	40.48	-126.18	4.7	80.0	1	0.37	0.54
42	10806	0806~1021	21~25, 68~73	>=6	920	13:24	23.57	70.28	4.7	0.0	0	0.00	0.00
					921	2:40	23.47	70.07	4.5				
43	10808	0808~1002	32~33.5, -117~-115.2	>=4	1031	7:56	33.51	-116.51	5.2	8.4	0	-0.22	0.51
44	990825	0825~1003	N Cal. >38,<-122	>=5.5	818	1:06	37.91	-122.69	5	6.0	0	-0.17	0.47

No.	Predictions				Earthquakes					Prob.			
	Date	Time (LT)	Location	M	Date	Time	Lat.	Lon.	M	(%)	Hit	Score	Var.
45	228	0228~0418	36.5~38.5,36~39	1M5/2M4	402	11:41	37.57	37.19	4.2	6.8	1	2.57	0.48
						17:26	37.65	37.23	4.4				
46	322	0322~0505	35.8~40,-120~-117	>=4	328	15:16	36.02	-117.87	4.3	37.7	1	0.90	0.49
47	629	0629~0820	Japan, <37	>=6	701	7:01	34.22	139.13	6.2	37.7	1	0.90	0.49
48	10320	0320~0504	N Cal., -126~-122	>=4.5	420	5:19	40.68	-125.32	4.8	29.3	1	1.11	0.51
49	10426	0426~0615	USA~Can,38~54,<-120	1M5/2M4	502	2:05	49.91	-130.15	5.3	71.7	1	0.45	0.52
50	10403	0403~0702	36.3~37.2, -121.5~-120	>=4	702	17:33	36.7	-121.33	4.1	18.8	1	1.53	0.54
Sum											**34**	**18.34**	
S.Dev													**4.78**
Total Score												**3.84**	

Note:

1. Shou's 50 predictions were reported to the USGS from 1994 to 2001. All of them are independent, e.g. No.17 and No.18 seem dependent, but No. 18 was made after No. 17 had hit an earthquake. Similar, No. 18 and No. 19, and No. 28 and No. 29 are independent, too. Shou's predictions have coarse and fine windows. Here are all coarse. No. 1~43 and No. 44~50 predictions rely on the clouds and georuptions respectively.
2. In Column3, LT is Los Angles Time, while in Column 6 and 7, Time is UTC. The magnitude 6.0 earthquake for No. 16 prediction occurred at 4:36 on 6 April UTC or at 20:36 on 5 April LT, mentioned in Column 3, so the prediction is correct.
3. In Column 4, Ale. Aleutian. Cal. California. Can. Canada. Med. Mediterranean. Mex. Mexico. Pas. Pasadena (34.138 N, 118.143 W).
4. All earthquake data are from the USGS (@12), except No. 29, which is from both the Northern California Earthquake Data Center of the USGS (@17) and Univ. of Nevada (@18).
5. In Column 5, M. Magnitude. 1M5/2M4 means one earthquake of magnitude 5~5.9 or two 4~4.9. In Column 10, we adopt the maximum magnitude if there are few recordings, as is customary.
6. In Column 8 and 9, Lat. Latitude. Lon. Longitude.
7. In Column 11, Prob. probability according to Shou's calculation (2).
8. In Column 12, '1' means the prediction is correct in time, location and magnitude, checked with "Peer on" i.e. assuming earthquake data is without error; while '0' means incorrect. Together, 34 predictions or 68% of them are correct.
9. In Column 13, Score adopts Brelsford & Jones' method (21). If a prediction has a probability **p** correctly, it will have a positive score –ln **p,** while a negative score ln (1-**p**) when it is incorrect. The total score is the sum of individual scores, or 18.34.
10. In Column 14, Var.: variance = $\mathbf{p}(1-\mathbf{p})[\ln \mathbf{p}(1-\mathbf{p})]^2$. The standard deviation of Shou's total score is 4.78.
11. The normalized score is the total score divided by the standard deviation of the total score (Jones (@13) – Jones (@14)). The normalized score for Shou's set is 3.84. Comparing it with the normal distribution (@15) or (22), the total probability of Shou's set is 0.000062.

Analysis of Errors

Let's look at the 16 misses. The prediction of 25 August 1999 was the result of a clerical error, Shou having submitted the prediction after the earthquake had already occurred. Five misses were due entirely to time window errors, in general the choice of too small a window. Such errors were a natural consequence of the process for developing an empirical method, as the time delay between precursor and earthquake is not known theoretically. Six misses were due entirely to area errors, because the earthquake clouds often appeared far from epicentres, and satellite data did not clearly reveal their origin

The other four misses were in magnitude. Two were due to a phenomenon in which the observed atmospheric feature came from two or more closely spaced impending epicentres. For example, Shou predicted an earthquake of magnitude more than or equal to 7 in the Indian Ocean with a latitude over 20S from 27 December 1999 to 10 February 2000, and likely in the area of latitude 25~28S, and longitude 60~80E by the cloud of Fig. 8. However, not one magnitude 7 earthquake, but six magnitude 5 earthquakes occurred in the time and the fine area instead (Table 5). The six earthquakes are the only sextuplets of magnitude more than or equal to 5 in the entire Indian Ocean within 3,000 days from 27 May 1994 to 12 August 2002. Similarly, prediction number 42 gives sets of twin earthquakes.

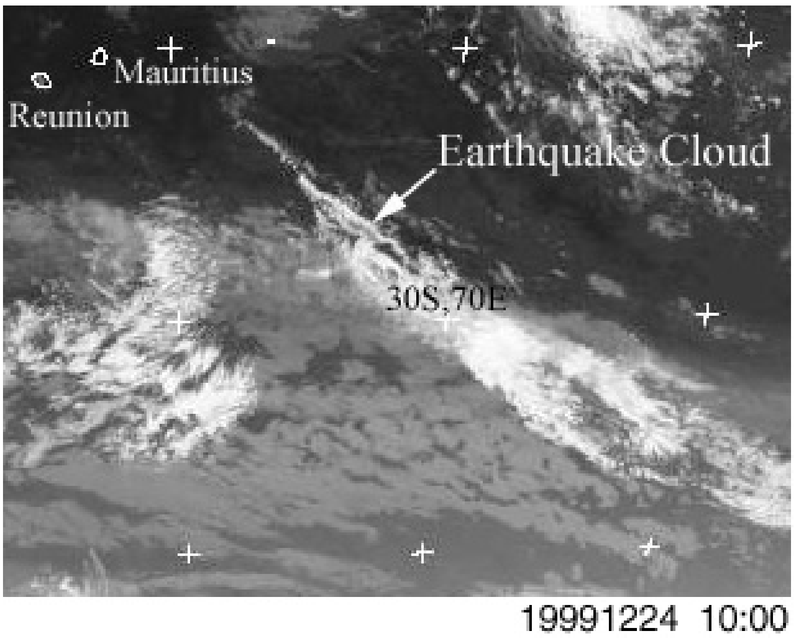


Figure 8: The Union of Six Earthquake Clouds
This infrared image of IndoEx satellite (@2) revealed a linear cloud, marked by arrow near 30S, 70E over the Indian Ocean at 10:00, on 24 December 1999. By this cloud, 550 km in length, Shou predicted a magnitude 7 earthquake over 20S in the Indian Ocean from 27 December 1999 to 10 February 2000, with a fine area window of 25~28S and 60~80E. However, not one magnitude 7 earthquake, but six magnitude 5 earthquakes occurred in this window on 9~10 February 2000 (Prediction No. 38 in Table 5).

Another difficulty is the uncertainty in even the highest quality earthquake data. For example, the USGS changed the magnitude of 5.8Mb in Rank “A” to 5.3Mb in Rank “A” for the Iran -Turkmenistan border earthquake on 19 November 1999. It implies error in Rank “A” reaching 0.5Mb, which is much higher than the 0.1Mb uncertainty quoted by seismologists. This is a significant problem both for the evaluation of earthquake predictions and the development of the empirical method.

The above analysis reveals that the few incorrect predictions do not cast doubt on the validity of the precursors, but instead suggest that more attention must be paid to data quality and data interpretation.

Impact of Space Technology

Clearly, the use of space technology has been essential to the development of an earthquake prediction method based on atmospheric precursors. Satellite imagery is by far the most practical way to obtain global round-the-clock coverage. A good example is the magnitude 6.1 Afghanistan quake of 4 February 1998. The portion of a global composite shown in Fig. 9 reveals the distinctive cloud that was used to make a successful prediction to the USGS.

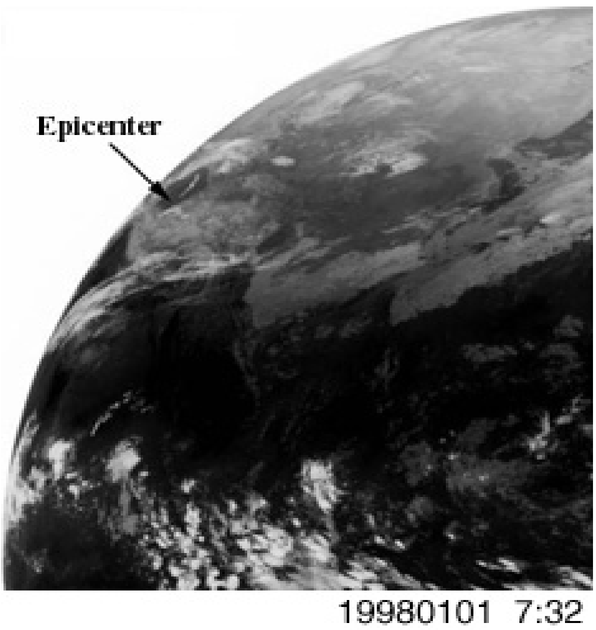


Figure 9: The magnitude 6.1 Afghanistan earthquake cloud
This image was taken from a composite of the Geostationary Meteorological Satellite, provided by University College London (@3). At about 7:32 on 1 January 1998, a hole with a line-shaped cloud inside appeared in a large weather cloud. The line-shaped cloud disappeared at about 16:25. Shou predicted an earthquake of magnitude larger than or equal to 6 in Afghanistan and its neighbours, with a coarse window of 25~41N and 53~105E from 5 January to 18 February, and a fine window of 30~37N and 58~95E, from 5 January to 4 February 1998 to the USGS. The 6.1 Afghanistan earthquake at Rustaq (36.83~ 37.31N, 69.5~70.11E) (@19) marked by the tip of the arrow, on 4 February proved both the coarse and fine predictions correct.

Using satellite images of atmospheric precursors, Shou has successfully predicted 50 earthquakes, including a pair of magnitude 6.0 in Xinjiang, China earthquakes on 5 and 6 April 1997, the magnitude 6.4 in Mexico on 3 February 1998, the 6.1 in Afghanistan on 4 February 1998, the 6.6 in Southern Iran on 4 March 1999, the 7.0 in Mexico on 15 June 1999, the 6.2 in Japan on 1 July 2000, and the 6.5 in Japan on 30 July 2000 to the USGS. He has also predicted to the public, among other earthquakes, the 7.0 Mexico earthquake on 15 June 1999, the 7.4 in Hector Mine, Southern California, USA, on 16 October 1999, the 6.2 in Japan on 1 July 2000, the 6.5 in Japan on 30 July 2000, the 6.8 in Seattle, USA, on 28 February 2001, the 6.5 in Western Iran on 22 June 2002, the 7.6 in Mexico on 22 January 2003, the 6.4 in the Gulf of California on 12 March 2003, the 7.0 in Japan on 26 May 2003, the 6.8 in Chile on 20 June 2003, the 6.0 in Yunnan, China, on 21 July 2003, the 6.8 in Bam, Iran, on 26 December 2003 and the twin earthquakes of magnitude 5.5 in Pakistan on 14 February 2004 (@1).

However, the scope of our work currently suffers from four important limitations. First, an earthquake cloud appearing in satellite images can pinpoint an impending epicentre from an earthquake cloud only when it condenses at the epicentre in cold surroundings, as it did in Bam. As a result, the area windows must often be made very large, thus reducing the usefulness of the prediction. For example, Shou had known of an impending earthquake of magnitude over 7 from Iran to Italy within 49 days following 16 July 1999 relying on a long, linear cloud imaged near Sri Lanka (Fig. 10); however, he did not know the exact epicentre until the 7.8 Turkey earthquake on 17 August 1999, because the images did not show from the cloud's origin.

Figure 10: The Magnitude 7.8 Turkey Earthquake Cloud
These infrared images were from the IndoEx satellite (@2) from 6:00 to 15:00 on Jul.16, 1999. At 6:00, a linear cloud appeared in a large clear sky near Sri Lanka. The cloud lengthened as it moved eastward, and then disappeared after 15:00.

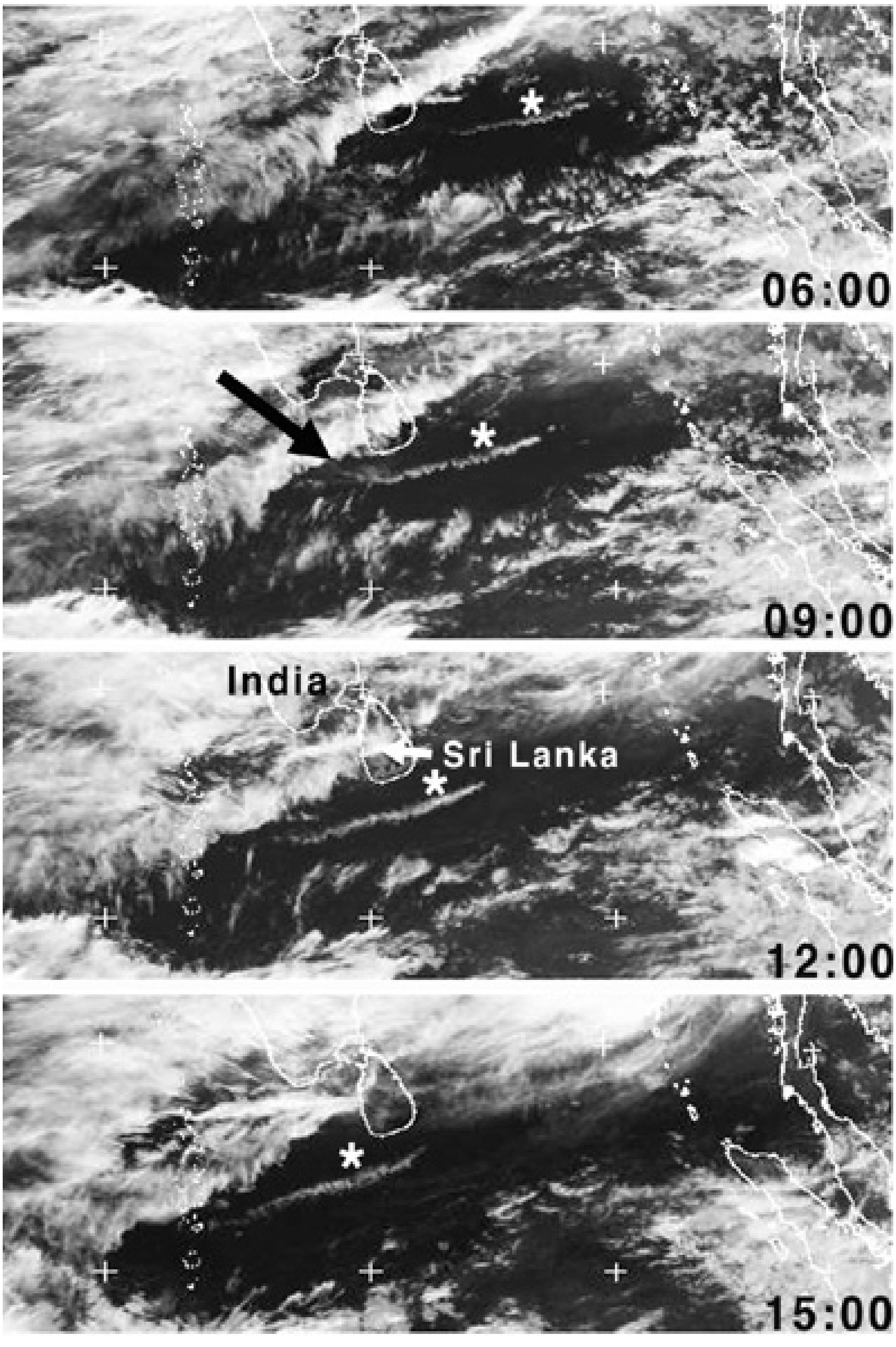


Figure 10 (ctd.) The tail (see 9:00) pointed to the northwest, and indicated that the epicentre would be in a region from Iran to Italy; however, the satellite images did not show the exact epicentre, and Shou did not know it until 17 August 1999 when the magnitude 7.8 Turkey earthquake occurred at 40.74N, 29.86E.

Fig. 11 shows a comparison between simultaneous visible and infrared images of California at 15:30 on 20 March 2001. The visible image clearly shows a dark trace of a geoeruption from Hollister, California, USA, by which Shou predicted an earthquake of magnitude more than or equal to 4 there, circled at the beginning of the trace, from 3 April to 2 July 2001 to the USGS and the public. On 2 July a magnitude 4.1 earthquake occurred there (36.7N, 121.3W) exactly. In contrast, the infrared image did not reveal the geoeruption. This comparison highlights the importance of selecting an appropriate imaging band and the target of the image post-processing to expose the origin of earthquake vapour. The existence of geoeruption phenomena suggests that if we could solve this problem, we may be able to pinpoint all large epicentres in satellite images, independent of their surrounding environment.

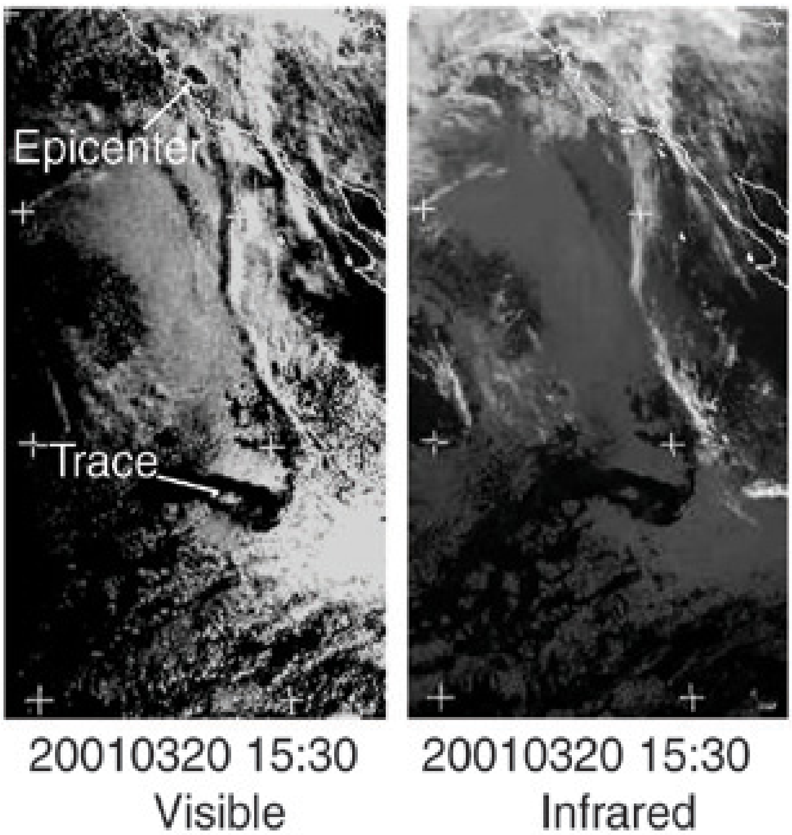


Fig. 11: A Comparison between Visible and Infrared Two simultaneous images, visible and infrared, were taken by Goes-West (@2) of the same location at 15:30 on 20 March 2001. The visible image clearly showed the black trace of a geoeruption from Hollister, California to the ocean, while the infrared did not. Shou used this geoeruption to successfully make prediction No. 50 in Table 5.

Second, many earthquake clouds and geoeruptions are likely missed due to their short lifetimes and sudden appearance. For example, the Northridge earthquake cloud existed for only 35 minutes according to Shou's visual record, and typical lifetimes range from half an hour to 10 hours. The frequency of public satellite images for some locations ranges from half an hour to six hours, depending on location, and even in high frequency regions individual images are often unavailable. The Bam cloud in Fig. 2 appeared at 2:00 on 20 December 2003, while nothing was seen in the previous image at 0:00. Increasing the image frequency would not only increase the likelihood of identifying an atmospheric precursor, but would also help to improve the reliability of predictions by clearly revealing the growth of the cloud or geoeruption from a fixed source. This may be more of a satellite data management issue than a technical problem.

Third, public weather satellite images do not have high enough resolution to resolve closely spaced atmospheric precursors, such as those shown in Fig. 7 and 8. As a result, multiple small earthquakes can be mistaken for a single large earthquake, as described in the Error Analysis section. On the other hand, the Advanced Very High Resolution Radiometer (AVHRR) can give 1.1-km resolution, much better than the 4 km of images for the public. The authors have not yet had the opportunity to study those data, but expect that the data will provide the necessary detail.

Finally, the amount of time needed to search satellite images by eye for atmospheric precursors severely limits the number of earthquake predictions that can be made by a single individual. To apply this prediction method to a large fraction of the world's earthquakes will require the development of satellite imagers and automatic image processing techniques that are tailored to find the hot vapour emerging at an impending epicentre. It is quite possible that both the imagers and the techniques already exist, and need only be redirected to this target.

With a moderate amount of international effort devoted to solving the problems of imaging, data processing and management, this method of earthquake prediction by atmospheric precursors could finally provide governments and communities around the world with information that was once thought unknowable: the time, place and size of every significant impending earthquake.

Acknowledgement

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@14 Jones, R.H. Dep. of Preventive Medicine & Biometrics School of Medicine, Univ. of Colorado Health Sciences Center
@15 Normal Distribution by DoStat Company of both Webster West in the Dep. of Stat. at the Univ. of South Carolina & Todd Ogden in the Dep. of Biostat. at Columbia Univ.
http://dostat.stat.sc.edu/prototype/calculators/index.php3?dist=Normal
@16 The Central Weather Bureau of Taiwan
http://www.cwb.gov.tw/V4e/index.htm

@17 The Northern California Earthquake Data Center
http://quake.geo.berkeley.edu/ncedc/
@18 Earthquake Data Catalog of Univ. of Nevada
http://quake.seismo.unr.edu/ftp/pub/catalog/
@19 UN Office for the Coordination of Humanitarian Affairs (OCHA)
http://www.reliefweb.int/w/rwb.nsf

II. KNOWLEDGE-BASED THEMES

BASIC SPACE SCIENCE IN ARAB COUNTRIES: PAST, PRESENT & FUTURE

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Abstract

Basic Space Science (BSS) is an important field of research, study, knowledge and culture. It has been the cradle of both eastern and western sciences. For this reason, many Arab countries plan to strengthen the Arab astronomy heritage by establishing a public academic and scientific Research Centre for Astronomy & Space Sciences. Jordan, Kuwait, Libya, Oman and the United Arab Emirates (UAE) are some of the Arab countries that are developing astronomy.

This paper summarizes astronomy and space sciences (ASS) activities in many Arab countries. The level and type of ASS activities differ in each country. Following are suggested future plans for some countries:

- The Gulf Observatory: An observatory of 2-metre optical telescope proposed by astronomers from the Arabian Gulf region, to be built on top of the Jabal Shams (2,980 metres above sea level), in the Sultanate of Oman.

- The Libyan Observatory: Libya signed a contract with a French company for building an observatory of 2-metre optical robotic telescope. They have now started a site testing programme for three chosen mountains.

- A joint venture between Jordan, Lebanon and the Syrian Arab Republic for building an observatory.

- UAE Centre for Astronomy & Space Sciences: A proposal under consideration for building a Space Centre that may contain: a radio and optical observatory, a planetarium and a Basic Space Science Museum in the Emirate of Abu Dhabi, UAE.

Introduction

The Importance of Basic Space Science (BSS)

BSS is neither a type of scientific and technological luxury in which humankind indulges, nor is it being fuelled by mere curiosity and insistent desire towards understanding the unknown in the universe and unveiling its secrets. In fact, BSS has its direct applications nowadays in various scientific and technological fields, including global techniques for ground-base astronomical and space observations, wireless communications, remote sensing of natural Earth resources using artificial satellites, the study of the environment and Earth bio-environment, as well as strategic and military applications and other newly-introduced technologies. At the same time, BSS applications are now common in other fields such as medicine, agriculture, computers, energy, image processing, industry, etc (Al-Naimiy 2001).

For the above and following reasons, the UAE is thinking of establishing a BSS research and educational centre (institute)**.**

i - Modern space and astronomical observations techniques take advantage of the use of the most cutting edge technologies. Exceptional technological developments have been encouraged by the needs of ASS research; many space ventures are based on and are aimed at astronomy. Successful applications of the advancement related to ASS are introduced in many important sectors of civil life:

1. In general: optics, fibre-optics, electronics, laser technology, research with each or all the wavelength of electromagnetic spectrum (spectroscopy), image analysis, telecommunications (satellites), new technologies for space research, remote sensing and geographic information systems for meteorology, atmospheric physics, physical oceanography, geosciences including the study of environment on land and in the seas, and the search for new natural resources use many of the techniques and types of instruments developed for BSS.

2. In particular: BSS has practical applications in navigation, time-keeping, calendars, climate, the Islamic Shariah (i.e., ascertaining the beginning of months in the Islamic lunar calendar, calculating the Islamic prayer times, which depend on sun set and sun rise, finding the Qibla, which is the direction for praying from any place on Earth…etc.), and other external influences on our environment.

ii - BSS is based on advanced physics, mathematics, sciences and technology and has a great influence on the intellectual development of an individual to deal with modern science and technology, leading to unlimited curiosity, imagination and a sense of shared exploration and discovery.

iii - BSS attracts young people to science and technology and will keep the Arab countries on track with scientific innovations and technological know-how.

iv - BSS deals with the Earth in both time and space and with our cosmic roots: the origin of the Sun, Earth and the elements constituting the human body and life itself.

v - BSS reveals a universe that is vast, varied and beautiful. Unlike most sciences, astronomy can be enjoyed as a hobby.

vi - BSS is an interdisciplinary subject; that could greatly contribute to tertiary education in the physical sciences such as chemistry, geology and physics. Two key areas where ASS could contribute significantly within the teaching and research of the physical sciences are the interaction of radiation with matter and the nature of information in signals.

BSS forces education in physical sciences away from the introspection of science for its own sake and towards science as a practical and useful tool.

vii – In the UAE there is a well-documented development in most branches of science and technology, except in BSS. It is therefore very important to start teaching BSS in schools and universities. To do so, it is essential to start by building an observatory with a sophisticated optical and/or radio telescope. Although the range of 1.5 – 2.5m optical telescope is suitable for the UAE, it should be equipped with state of the art technology.

This observatory could be useful for many institutions such as:

1- Universities (physics, mathematics, computer sciences and engineering departments, for teaching and research purposes in graduate and postgraduate studies).

2- Ministries and governmental institutions; such as those dealing with religious endowments (Awqaf) and Islamic affairs, communications, education and tourism.

The suggested UAE space and astronomy research centre will be an important and useful organization, because it will be designed for astronomical, space and Earth science research, teaching and for public use, based upon the fundamental philosophy of providing every visitor with a real experience. It will also be engaged in educational activities that are linked to schools, universities or life-long education to spread astronomical observation and increase the number of astronomy amateurs in Arab countries, as well as in observational research activities. This will allow the visitors to discover and document wonders of their cosmos and to access the latest information about astronomy, astrophysics and space science, thereby enabling them to think about nature, the environment and the future of the human race in general.

In addition to all of the above advantages of astronomical technologies, the observatory will be open to many visiting international astronomers and scientists, becoming a reputable international scientific centre of excellence. Furthermore, the UAE could become a member of many international astronomical and space unions and societies such as the International Astronomical Union (IAU), the Committee on Space Research (COSPAR), etc.

Arab Astronomical Heritage

Astronomy has influenced Arab history and culture, through its practical applications, as well as its philosophical and religious implications. This is reflected in calendars, particularly the lunar calendar (the Hijra Months), mythology and a variety of art forms. Dating back 4,000 years, astronomy was well advanced in Mesopotamia and Egypt, where science and technology flourished in continuous interplay with religions, substantially influencing the course of history. The achievements of Arab and Muslim scientists in the field of astronomy are well-known. Their fingerprints are apparent in the Arabic names of the celestial bodies that are even now used in astronomical observations throughout the world.

Islamic culture in the Near and Middle East partly grew out of the rich civilizations of the Babylonians and Chaldeans in the preceding centuries and millennia. The fact that a large number of stars in the sky still carry Arabic names (some of which, as attested by their occurrence in Homeric poems, must go back to at least the second millennium B.C.); or that a considerable fraction of astronomical terminology currently used, in particular as regards instrumentation, still remains in its Arabic origin. Such terms include alhidade, almucantar, astrolabe, azimuth, nadir, sundial, zenith, etc.

During the period between the 11^{th} and 15^{th} centuries, Arab astronomy attained great positions, resulted in important achievements, and greatly influenced other sciences. Following are some examples of such achievements:

- Arab astronomers and their discoveries in the field of planetary theories, which refer to the various constructions of geometric models that represent the modern concept of the celestial spheres and planets. This was a very important episode in the history of sciences, and it has been extensively studied (Saliba, 1994).

- Computational mathematical astronomy, which was at that time called alzyaj (sing.zij) (Kennedy 1956).

- Astronomy, which covered problems related mostly to religious matters and was usually treated in the miqat (time keeping) literature and engaged the most active astronomers of that time (Ahmad 1995).

- Astronomical instruments, which shows the most brilliant developments in Islamic instruments made during those centuries (King 1987 and 1988).

- Institutions of astronomy, namely the most impressive observatories that were developed during this period into veritable professional centres

- Many famous and great astronomers appeared during that time, such as Al-Kindy, Al-Battani, Ben Qurra, Ibn al-Shater and many others, whose names and contributions are still well known (Said 1983).

Due to its importance and fast development in the world, BSS should be established at a small or large scale in every Arab country and should be included in the science curriculum of schools and universities, in order to increase public knowledge, understanding and appreciation of the field, as well as for educating scientists, engineers, teachers, researchers and other science and technology personnel. There are many reasons why BSS is useful, important and should be included in school and university curricula (Percy 1999), at the same time there are challenges to effective teaching and learning. Basic Space Science or any other subject can be taught, but there is no assurance that it will be learned (Baxter 1989, Nussbaum and Novak 1982, Sadler 1998, and Percy & Mattai 1999). High school and undergraduate students, many teachers (Woodruff et al. 1999), and the general public have deeply-rooted misconceptions about BSS topics: day and night, seasons, moon phases, celestial coordinate systems, eclipses, gravity, light, celestial motion and crescent visibility. Ahlgern (1996) and Sneider (1995) suggest strategies for teaching more effectively.

It is important to relate the curriculum to local Arabic language, culture, historical background and other needs. This is true in all parts of the Arab countries, and helps to meet another important challenge-- reaching women, minorities and the economically disadvantaged. In many countries, the education system favours rote memorization of lecture or textbook material. While this ‘classical’ approach to teaching has some merit, it does not prepare students to develop new solutions to new problems.

The problem is how to maintain the sense of awe and excitement that BSS could provide. The standard astronomy topics in the school curriculum are: day and night, seasons, moon phases, eclipses, tides, comets and planets. Students frequently ask about the peculiar celestial objects and sudden events (i.e. comets, eclipses, supernova, black holes, etc.) and sometimes about the origin and fate of the universe, the origin of life, etc.

Summary of the present BSS activities in a few Arab countries

BSS activities in the Arab World are applied differently in different countries. Egypt and Jordan are quite active in this regard, the Arabian Gulf countries less so and other countries have no activities at all.

Egypt

The following organizations are involved with BSS in Egypt:

- Research and postgraduate studies are carried out at the National Research Institute of Astronomy and Geophysics (in Hellwan). Kottamia observatory operates a 2-metre optical telescope with a photometer, a spectrograph and a charge-coupled device (CCD) camera. The observatory was built in 1963. This telescope is the largest optical/infrared telescope in North Africa and the Middle East. Carl Zeiss Company was recently contracted to modernize the optical system of this telescope (Deebes & Heileman 1999). The Institute plans to build a radio telescope at Abu Simbel in southern Egypt as part of the European Very Long Baseline Interferometry (VLBI) Network, or EVN, to bridge the gap between the radio telescope in Western Europe and the radio telescope at Hartebeesthoek in South Africa, (Shaltout 1999).

- Teaching of and training in BSS are provided in a few universities, particularly at Cairo University, which has a good astronomy department and about 25 astronomers. It offers two Bachelor of Science degrees in Physics/Astronomy (interdisciplinary) and Astronomy (single discipline), in addition to Master of Science and doctoral degrees in astronomy and space science. The department of astronomy at Cairo University contributes to different fields of BSS, such as astrophysics, astrochemistry, celestial mechanics, solar physics, cosmology and space physics.

- In schools, astronomy is a part of the general science course at the primary and preparatory levels and a part of the physics course at the secondary level.

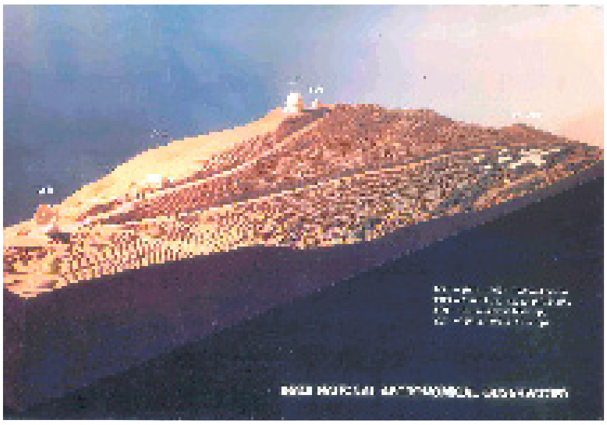
Iraq

Iraqi astronomers and space scientists started from a good position by establishing and developing ASS in 1980. They built The Iraqi National Astronomical Observatory, a computerized observatory in the Northern part of Iraq. The observatory contained the following instruments:

- Large Optical Telescope (LOT) of 3.5-metre reflector with infra red and UBVIR photometers and different types of spectrographs such as Echelle, Code, and Nasmyth.

- Small optical telescope (SOT) of 1.5-metre reflector with different types of spectrographs and photometers with many auxiliaries for both SOT & LOT telescopes.

- 30-metre mm Radio telescope (MRT) with a receiver system plus its auxiliaries. The observatory was a joint venture of three German companies ZEISS, MAN and KRUPP. The cost was U.S $150 million (1980 price). The observatory was built on top of a mountain 2,200 metres above sea level, with a very good observational site less than 0.01 arcsec seeing conditions (Al-Naimiy 1986). Unfortunately, this observatory was damaged during the two wars (1980 and 1991). Iraqi astronomers might now need help for rebuilding the observatory as far as the large optical telescope is concerned. (It is the only part of the observatory left undamaged, because it was stored in Baghdad).



The current situation of BSS in Iraq is as follows:

- Space Research Centre, which is connected to the Ministry of Science & Technology in Baghdad. The main research programmes are remote sensing, wave propagation, communications, astronomy and astrophysics.

- Physics departments in most Iraqi universities offer courses in astronomy and astrophysics. The College of Science at the University of Baghdad has a good astronomy department, established in 1998 for undergraduate and postgraduate studies in ASS. The College also has a small observatory, Al-Battani Observatory, which contains two telescopes: a 40cm reflector and a 20cm refractor, purchased from Goto Company of Japan. The observatory is located in Tarmia, about 50 km north of Baghdad.

- Secondary schools include small general topics about astronomy in the physics courses that they offer, covering such topics as day and night, moon-Earth system, the solar system, stars.

- Additionally, there are a few small astronomical clubs and planetariums under the supervision of the Ministry of Youth and Sports, as well as occasional television programmes about special subjects in BSS.

Jordan

Research, teaching and popularization of BSS are very good nowadays in Jordan when compared with most Arab countries. The following organizations are concerned with BSS in Jordan:

- Universities: Astronomy and astrophysical courses are offered to undergraduate students in more than five universities, but the main ASS activities are concentrated in the Al al-Bayt University in Mafraq (http://alalbayt.aabu.edu.jo). In 1994, this university established the Institute of Astronomy and Space Science (IASS), which contains:

(a) Master of Science research projects and curricula in astronomy and astrophysics; space sciences; remote sensing (science and technology); and environment and water resources.
(b) Maragha Astronomical Observatory (MAO): This contains a 40 cm Meade Schmidt-Cassegrain optical telescope and a CCD camera (Pictor 1616).
(c) Scientific Activities in ASS: Beside a few national meetings, IASS managed to organize two international meetings. The First International Conference was held at the IASS in 1998. The conference was attended by more than 50 astronomers and space scientists from 18 countries (http://www.seas.columbia.edu/~ah297/un-esa/ws1998-jordan-astronomy.html). The proceedings of the conference have been published by Al al-Bayt University Press (Al-Naimiy & Kandalyan 2000). IASS also hosted the Eighth United Nations/European Space Agency (ESA) Workshop on Basic Space Science: Scientific Exploration from Space, which was organized jointly by the UN, ESA and the Government of Jordan and was hosted by the Al al-Bayt University, in March 1999. More than 120 astronomers, scientists and students of basic space sciences from 35 countries attended the workshop (http://www.seas.columbia.edu/~ah297/un-esa/activities-html#1999). The proceeding of the workshop was published as a special volume of Astrophysics & Space Science Journal (Dayson & Lamb, 2000).

- Arab Union for Astronomy and Space Sciences (AUASS) (http://www.jas.org.jo/union.html): This union was established in 1998 as an outcome of the second Arab Conference on ASS, held in Amman in 1998. More than 100 astronomers and scientists from 14 Arab countries, in addition to observers from France, Italy and the United States participated in the conference. The participants decided to establish AUASS with headquarters in Amman. The aim of the union is to develop ASS in Arab countries with the cooperation of international ASS institutions, through conferences, meetings, publications, joint research projects, etc. (Al-Naimiy & Konsul, 2001).

- Jordanian Astronomical Society (JAS), (http://www.jas.jo/index.html): It is an organization that promotes amateur and sometimes professional ASS. JAS was founded in Amman in September 1987 and has headquarters at Haya Cultural Centre.

  Since its inception, JAS has promoted ASS not only throughout Jordan, but also in the rest of the Arab World. It has more than 250 members and promotes ASS as an aid for education and development in universities, schools, educational television, radio programmes, planetariums, public lecture, etc. It has a good observing programme in Al-Azraq camp for astronomical events, such as comet sightings, meteor showers, lunar and solar eclipses, etc (Al-Naimiy & Konsul, 2001).

- Islamic Crescents' Observation Project (ICOP): Aims to gather the largest possible number of lunar observers worldwide. This is for predicting the visibility of the new moon, which is the most important application of astronomy in the Islamic world, as it is used to ascertain the beginning of the Islamic lunar months (http://www.jas.org.jo/icop.html). ICOP is supervised by a committee from AUASS, IASS & JAS called Crescents' Observation and Mawaqeet (timings) Committee. The members are from different parts of the world, particularly from Islamic countries (http://www.jas.org.jo/come.html).

- Teaching BSS in Jordanian Schools: General astronomy courses are taught in secondary schools. The courses contain general information about the Earth-Moon system, day and night, seasons, the solar system, stars, clusters, the Milky Way, galaxies and the universe.

Other Arab Countries

Algeria: Astronomy in Algeria has existed since the last century when the Observatoire de la Bouzareah was built to take part in the famous French project called Carte du Ciel. In 1980, the Observatoire de la Bouzareah became the Centre de Recherche en Astronomie, Astrophysique et Géophysique (CRAAG). The main goal of the Department of Astronomy at CRAAG is to promote the development of astronomy through education and research. Several scientific projects are under way, ranging from solar physics to cosmology, in collaboration with international institutions. Two new projects are in progress: the measurement of the solar diameter with an astrolabe, which will be transfered to Tamanrasset in southern Algeria, and the development and installation of a photometric station in southern Algeria. There is no teaching of astronomy in Algerian schools or universities, but the Department of Astronomy at CRAAG accepts students for Master and doctoral degrees in astronomy. The computing facilities at CRAAG have recently been improved with the acquisition of several new Sun stations. There is as yet no direct internet or email access to CRAAG. Algeria has two telescopes: a 35-cm refractor and a 30-cm reflector http://www.saao.ac.za/~wgssa/as2/sadat.html.

Syrian Arab Republic: Plans exist for building a 2-metre optical telescope. The country has an active society, the Syrian Cosmic Society. It has an agreement with Jordan and Lebanon for building the Middle East Observatory.

Libyan Arab Jamahiriya: Plans exist for building a 2-metre robotic optical telescope. Observations and research are being carried out for choosing a suitable site out of three being studied. They had contract with French company for building the observatory.

The Gulf Observatory: An observatory with a 2-metre optical telescope proposed by astronomers from the Arabian Gulf region (Bahrain, Kuwait and the Sultanate of Oman), to be built on top of the Jabal Shams (2,980m above sea level), in the Sultanate of Oman. There is a plan in the near future for a site-testing programme for this mountain.

UAE: Plans exist for establishing a BSS centre. A general course in astronomy is offered by the Physics Department at the UAE University. About 1,000 students enrol in this course each semester. Additionally, there are two astrophysics courses offered to physics department students (http://www.fsc.uaeu.ac.ae/depa_list.html). Abu-Dhabi has an active astronomical society, the Emirates Astronomical Society (http://www.falak.ae/).

BSS cooperation between Arab Countries: Enhancing BSS in Arab countries requires cooperation with international institutions in general and among many Arab universities & organizations in particular. Establishing good BSS in any region cannot be accomplished without strong cooperation between different communities. In Arab countries, everything for BSS development is available (such as budget, personal, sites, environments, etc); the only thing missing is cooperation and scientific support from international organizations and scientists.

Arab Observatory : Building good, modern observatories in the region jointly by Arab astronomers and scientists is essential and will be an excellent step toward developing astronomy and astrophysics, particularly when the observatories contain modern size optical telescopes with their auxiliaries, as well as a millimetre radio telescope to be part of any International VLBI system. Keeping in mind that there are very good sites in different parts of Arab countries, particularly in those places were observations can be made of both southern and northern parts of the sky. It might be useful if the observatories were to be built in collaboration with AUASS (Al-Naimiy & Konsul, 2001). It is very useful for Arab astronomers to examine Querci's proposal for the Network of Oriental Robotic Telescopes (NORT) Project (Querci 1998a, b, c, 1999a & b).

Suggested UAE Observatory

The UAE is interested in building an astronomical observatory with radio and optical telescopes plus the necessary accessories and instrumentations for both telescopes with related laboratories and workshops (electronics, mechanics, electrical, optical and computers). The observatory should satisfy the following general requirements:

1. The Radio Telescope

The observatory should have a MRT with a 20-30 metre dish, high-resolution mapping for the structure of distance quasars, and if possible, it should be connected to the international VLBI system, to be used for VLBI applications. The telescope should be equipped with accessories and instrumentations, such as a cryogenic receiver, hydrogen masers and the components of a high precision VLBI station, if necessary, plus the newest software. If possible, the telescope should be fully computerized and remotely controlled. The geographic position of the UAE with regard to the international network in VLBI or Very Large Array (VLA) is superb. It will be core locations in accord to the interferometer technology. The coordinates are: Longitude = 24.00N; Latitude = 54.00E.

Even for an optical observatory, the site will be very important, because the astronomers can cover, beside the northern celestial hemisphere, part of the southern-hemisphere as well. Building a VLBI telescope and facilities would be easy, as far as the common visibility with the European, Russian and South African networks are concerned.. In the following map, one can see how the location of the UAE is central to the VLBI international network.

2. The Optical Telescope

i. Suggested Aperture range:

The suggested aperture range for a state of the art optical infrared reflector telescope is 1.5-2.5 metres (Light weight mirror technology). The telescope should be fully computerized and remotely operated via satellite link. It should have the required general instruments such as sensors, auto-guider, infra red camera and the optical imager, etc. to be mounted at the end of the Cassegrain telescope or any other place convenient for the use of the observer depending on the telescope technology. The UAE is thinking of building a small observatory with a 50-60cm optical telescope on Jabal Haffet, as well as a large observatory on a higher mountain, of perhaps 1,500m.

ii. General Specification (Tracking and Pointing Accuracy):

The Pointing and Tracking Model should be automatically and continuously evaluated, both telescope pointing and tracking simultaneously, and apply correction in real time mode to both of them. The telescope must point precisely on the target celestial object, and then autonomously track to a reasonable fraction matches with system and for a reasonable duration. It must retain the precision while continuing to function at rates approaching thousands of observations per night for its working lifespan. The tracking and pointing accuracy suggested above depends on the telescope technology.

3. Dome and Climate:

The observatory dome should provide excellent protection from environmental influences, particularly the weather. There are two technical solutions for housing the observatory: a dome, which would be a rotating hemispherical structure on top of the building; or astronomical observation by opening two parallel arranged gates, movable in horizontal direction and providing a suitable width gap, running along a meridian from the horizon to the zenith with a continuation over the zenith. This means that the dome enclosure system should be combined with the electrical and electronic systems, environmental control systems and integrated computer control software.

4. Instrumentations and Technical Support:

The telescope and the observatory should have most of the related equipment: accessories, software features and instrumentations (e.g. CCD Camera), spectrographs, photometers (UBVRI + IR), with different kind of filters for different celestial objects.

5. General Remarks

The proposed astronomical project should include a training programme for national researchers, specialists and technicians. This training would be scheduled during the following phases:

- Manufacturing the telescope and the related instruments (in the factories).
- Installation of the observatory, including the telescope, accessories and the related instrumentations in the site.
- Operation of the observatory during the maintenance period.

The number of trainees will depend upon the type and size of the observatory, taking into account that the training programme should include most of the observatory functions, including the maintenance.

6. The site of the UAE Observatory

In accordance with the above information, the site for a 1.5 – 2.5m telescope should be far away from light and dust pollution, therefore the UAE needs to be surveyed and scanned for all the geographic areas to find a suitable site for the observatory. To judge on the most suitable site, all the candidate sites must be subjected to a whole year of testing and research and then the most appropriate site would be chosen according to the observational and research results including optical and meteorological investigations (dryness, darkness, water vapour, etc). The investigation should include photometric research, observation of the clouds in the sky, identification of constellations and the Milky Way, quality of night sky and the contents of the horizon by the traces of haze and dust at the time of sunset and at the end of twilight .

Regarding Jabal Haffet, the site might be suitable for the observation of planets and bright stars up to approximately 8 - 10 magnitudes. This is true if scientific treatment of the lighting system can be taken into account, noting that the telescope should have a highly sophisticated instrument like a CCD camera. The site has advantages of accessibility and proximity to the UAE University and the city of Al-Ain, but the disadvantages include light pollution and the small numbers of photometric nights per year, it is not comparable to international sites such as Mauna Kea or Chile.

Other Suggested functions

1. Suggested contents of the Space Centre:

The ‘space city’ could have the following *preliminary* structure and content:

i- Space and Astronomy models, e.g. space crafts, rockets, space ships, satellites, which can be built in such a way that visitors would be able to experience the simulation of real space flight;

ii- Rooms (theatres) with their insides similar to the surfaces of the near celestial objects like the Moon, Mars etc. These rooms should portray the physical properties and environments of those celestial objects. This should be done in cooperation with international institutes and universities;

iii- 3-D models of the solar system;

iv- Demonstration of the life of astronauts in space;

v- Models in astronomy and astrophysics, stellar motions, Earth-Moon system, in a simple experimental manner to demonstrate the motion of different celestial objects.

vi- A Planetarium with state of the art, frontier technology equipped with the latest information, slides and movies about the exploration of the universe. The planetarium should include shows for all ages. It could be divided into different levels, e.g. for 6-9 year old children, for 10-12 year old children, for secondary school students, for teenagers and university students, and finally for the general public. A part of the programme should be adapted to the national history and culture of the UAE and the Arab and Muslim achievements in astronomy, mathematics and optics.

2. Planetarium projection

The planetarium should generally conform with the following specifications:

- Projection of the stars visible to the naked eye, the Milky Way, open star clusters, gaseous nebulae and galaxies.
- Projection of the Sun, the Moon and the planets visible to the naked eye (Mercury, Venus, Mars, Jupiter and Saturn; the Earth as seen from extraterrestrial vantage points).
- Presentation of the rising and setting of all celestial bodies (diurnal motion), the changing aspect of the sky during the year (annual motion), the change of geographical latitude (polar altitude motion), and rotation about a vertical axis (azimuthal motion).
- Some systems permit the simulation of flights across the solar system and observation from other planets.
- Didactic projections (astronomical coordinates, great circles, scales and markers).
- Dome lighting and special lighting effects.
- Lift for lowering the projector to below the floor.
- The planetarium should be equipped with the latest technology.

3. Other Requirements

The ‘space city’ should also contain a scientific museum with different science and technology areas, to be used for general education, teaching and training such as:

- The heritage of the Arabs and Muslims, highlighting their contributions or achievements in science, particularly in astronomy. This should be presented in a simple manner in order for it to be understood by all the visitors.
- A display of some of the old instruments used in physics, astronomy, chemistry, geology, mechanics, etc, particularly the ones invented by the Arabs (i.e. Astrolabes, sundials, quadrant, etc.), the use of the Arabic astrolabes through the deserts of Arabia and Sahara, as well as the description of the Arabic and Islamic astronomy, the observatories and their discoveries until the European Renaissance with names of famous scientists such as: Thabit ibn Qurrah (9th Century), Al-Farghani (9th Century), Al-Batanious (9th Century), Al-Kindy (11th Century), Al-Beirony (11th Century), Al-Zarqali (12th Century), Ulug-Begh (14th Century), Ibn Al-Shater (15th Century).
- Part of the museum might be dedicated to natural history.
- The offer should include a clear training programme for a suitable number of technicians, engineers, physicists and computer software specialists.

Conclusion

Two main centres could currently be associated with this initiative: the UAE Space City (USC), and the UAE Astronomical Facility (UAF). The UAF would be oriented towards supporting higher education and university level astronomical and space science research and development, hence its centre-piece would be the optical and radio observatories, located on or near Jabal Hafeet, with a major support centre comprising assembly and lecture halls appropriate to hosting sizable conferences as well as laboratory and classroom facilities, which would be built in association with or in proximity to the already established infrastructure of the UAE University in Al Ain.

The USC would be established in the vicinity of the city of Abu Dhabi, and would focus on providing the general public with inspiration and awareness of the importance of science and technology in their own lives and especially in the lives of their children, and on inspiring younger students towards a career in science through the message of astronomy and space science. These themes would be developed by the introduction of the important history of Arabic and ancient Middle-Eastern discoveries and contributions to the science of astronomy up to and including the present epoch, via the Astronomy and Space Museum, the Interactive Astronomical Image Gallery, and the deeply moving Planetarium show experience, using a range of topics, changing according to monthly themes, to bring many viewers back in time, to refresh them, recharge them with enthusiasm, and inspire them to seek their own way in the quest for knowledge and discovery.

With a 150-seat planetarium, for example, there would be every reason to encourage classroom groups of school children from virtually every nation of the Arab World to come to Abu Dhabi to gain this experience. It would be such an experience to see the wonders of the universe, and participate in personal hands-on space and astronomy activities, space-camps, flight simulators, observe real-time solar activity with a dedicated solar imaging telescope, see special exhibits depicting current space activities such as comet sightings, asteroid missions, lunar and Mars exploration activities, space satellites, activities on the International Space Station.

There would always be a connection to the activities at the Jabal Hafeet UAE Astronomical Observatory. This aspect of the USC would both stimulate and educate the public at large, and give rise to new generations of students to populate the science curriculum of the UAE University in Al Ain and indeed all of the nation's colleges and universities as well. Such a growing awareness and affinity with sciences, combined with the great moral and spiritual strengths imbued through Islam give tremendous promise to a most fulfilling future for all the peoples of Abu Dhabi, the UAE and indeed the entire Arab World. In a country encouraging the development of science and technology, such as the UAE, it is natural to build a large and important ASS centre.

One of the main goals of the space initiative is to promote the Arab astronomy heritage and to become a core scientific research centre not only for Arab countries, but for all the Middle East and perhaps for Asia. It will also provide, on a continuous basis, information on the space sciences to the public community. It will show how important space science and technology is for humans. The project will concentrate on scientific research, education, learning, knowledge and scientific entertainment. This will be through the exploration of the universe and the discovery of the cosmos and celestial objects, which gives great achievements to the human community.

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NEW EXPLANATION FOR LENGTH SHORTENING OF THE NEW CRESCENT MOON

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Abstract

The observation of the new crescent moon is the main motivation for the installation of observatories in Arab and Islamic countries. Astronomers in these countries devote a part of their research time to this subject. Using the Astrophysics Data System (ADS) literature, this paper discusses the cause of length shortening of the new crescent moon.

Andre Danjon noticed that the length (cusp to cusp) of the new crescent moon was less than 180 degrees. Danjon suggested that the shortening was due to the shadows of the lunar mountains. McNally attributed the crescent shortening to 'atmospheric seeing'. Schaefer suggests that length shortening is due to a sharp fall in brightness towards the cusps.

This paper attributes length shortening to the Blackwell contrast threshold. The thin crescent is considered as a group of discs of varying angular size, and each has its equivalent Blackwell disc. The largest disc is at the centre of the crescent. Discs become *smalle*r when one moves in the direction of the cusps, therefore Blackwell thresholds become *higher*. According to this model, if one knows the crescent luminance, the crescent width and the background luminance, one can calculate the visible length of the crescent.

As a by-product of this method, the author and his students succeeded in observing Venus at noon with the naked eye!

Introduction

In August 1931, Andre Danjon[1] of the Strasbourg Observatory, France, noticed that the length (cusp to cusp) of the crescent moon, which was only 16.6 hours before conjunction, extended by only 70-80 degrees instead of 180 degrees. Danjon suggested that the shortening was due to the shadows of the lunar mountains. McNally[2] of the University of London, United Kingdom, did not accept this interpretation. He showed that the height of the lunar mountainous terrain compared to the lunar radius is not sufficient to be the cause of shortening. Alternatively, he attributed the crescent shortening to 'atmospheric seeing'. Schaefer of the Goddard Space Flight Center of the

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United States, rejected McNally's explanation showing that the resolution of the human eye is larger than the size of the crescent disc so that "seeing" has no effect on the perceived width. Schaefer suggested that length shortening is due to a sharp fall in brightness towards the cusps, emphasizing that detection threshold does not depend on the surface brightness of the Moon, but on the total brightness integrated across the crescent. He points out that as the extreme parts of the crescent are narrower than the resolution of the eye then:

"the detection threshold does not depend on the surface brightness of the Moon, but on the total brightness integrated across the crescent"(QJRAS, 1991, 32, P.271).

This paper disagrees with Schaefer's suggestion because human vision is more sophisticated than explained by Schaefer. Recent research (http://www.webvision.med.utah.edu/GCPHYS1.HTM) shows that human vision involves the simultaneous interaction of the eye and the brain through a network of neurons, receptors and other specialized cells. The retina is the beginning of the nervous system that transports information to the brain. It contains neural circuitry that converts light energy to action potentials that travel out the optic nerve into the brain. A direct 3-neuron chain is the basic unit of transmission (photoreceptor to bipolar cell to ganglion cell). Light falls on the retina, where it is transformed to an action potential that ganglion cells convey to the brain. The retina is not like a video camera; it does not send a point by point intensity of its illuminations. Rather, the important feature that the retina detects is contrast, i.e. differences in light intensity between points in the retina.

One way to express the luminance contrast C is as follows:

$$C = (L - L_B)/ L_B$$

where L = luminance (surface brightness) of the stimulus

and L_B = luminance (surface brightness) of the background

Contrast Threshold (C_{th}) is a measure of the ability of an observer to distinguish a minimum difference in surface brightness between two areas.

Size is the most generally recognized and accepted factor in seeing. Contrast threshold is dependent upon the size of an object, which affects the size of the image on the retina. The important aspect of size is not the physical size of the object, but the visual angle that the object subtends at the retina.

If the retinal area that is illuminated is small enough, then the photons will fall entirely within the centre of the receptive field. If enough photons fall into the receptive field, the ganglion cell will respond by firing. According to *Ricco's Law* of spatial summation, if one increased the area of the stimulus so that it was still within the centre of the receptive field, then more photons would be collected over this larger area and therefore, a lower intensity of light would be required[3]. *Ricco's Law* of spatial summation has been completely discarded by Schaefer:

“ the experiments (see also Blackwell 1946) show that unresolved circles of light have a threshold that is independent of the source size, yet which depends on the total brightness within the circle. The basic idea is that all that matters is how much light is received by any resolution element of the eye and not how the light is spread over the ‘pixel’” (QJRAS, 1991, P.269).

Schaefer is one of the biggest contributors to the subject that this paper discusses, but his above-mentioned paper shows that he had a problem with some photometric definitions such as *brightness*, *surface brightness*, *integrated brightness* and *total integrated brightness*. In spite of Schaefer’s confusion (i.e. if one were to neglect his length shortening interpretation), Schaefer got very good results represented in his Fig. 2 (QJRAS, 1991, P.270).

Roger Clark explains the Blackwell 1946 data, in his book titled "Visual Astronomy of the Deep Sky". Clark has added additional comments since the book's publication in 1990, which can be accessed at http://clarkvision.com/visastro/omva1/index.html.

On that website, Clark illustrates Blackwell 1946 data in a diagram (his Figure 2.6) which is represented in this paper in Fig. 1, and which he explained as follows:

“Here we notice that for objects with small angular sizes, the smallest detectable contrast times the surface area is a constant. As an object becomes larger, this product is no longer constant. The angle at which the change occurs is called the critical visual angle. An object smaller than this angle is a point source as far as the eye is concerned. (A point can be considered the angular size smaller than which no detail can be seen.)”

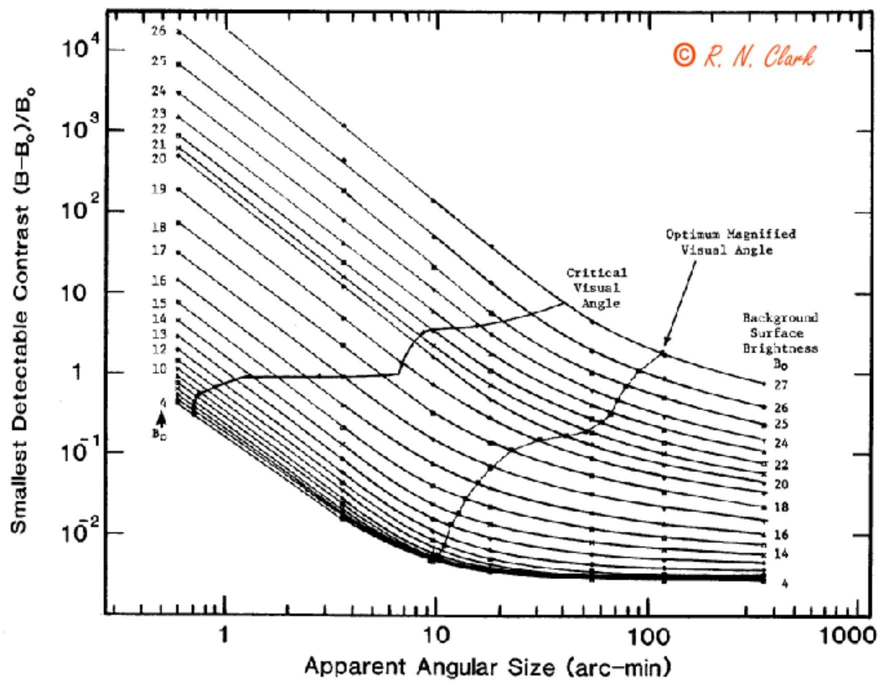

Fig.1: The visibility of small stimulus -smaller than the critical visual angle- is characterized by the left side curves of Clark’s Figure. From these curves we find that the stimulus visibility always depends on its luminance, its diameter and the background luminance even if it is smaller than the critical visual angle. (From http://clarkvision.com/visastro/omva1/index.html)

In effect, Clark specifies - by the previous explanation - the domain of utilization of *Ricco's Law*, which should be less than the critical visual angle.

For stimulus smaller than the critical visual angle, i.e. on the left side of Fig. 1, we conclude two things: one was mentioned by Clark himself, the other was mentioned neither by Schaefer nor by Clark :

- If the contrast between surface brightness of the stimulus and surface brightness of the background is higher than the Blackwell contrast threshold, then the object is seen as a point source.

- Or if the contrast is lower than the Blackwell contrast threshold, then the object could not be seen.

Therefore, the visibility of small stimulus –(smaller than the critical visual angle) is characterized by the left side curves of Clark's Figure. From these curves we find that the stimulus visibility always depends on its luminance, diameter and the background luminance, even if it is smaller than the critical visual angle (Fig. 1).

Method and Measurements

The thin lunar crescent should be considered as a group of discs of varying angular size, and each has its equivalent Blackwell disc (Figure2a). The largest disc is at the centre of the crescent. Discs become *smalle*r when one moves in the direction of the cusps, therefore Blackwell thresholds become *higher* (Figure1a). To obtain Blackwell's Contrast Threshold C_{th} for discs of diameters less than 0.6 minute of arc, the data in table VIII of Blackwell (1946)[4] was extrapolated. Figure 2b is an example of those extrapolations.

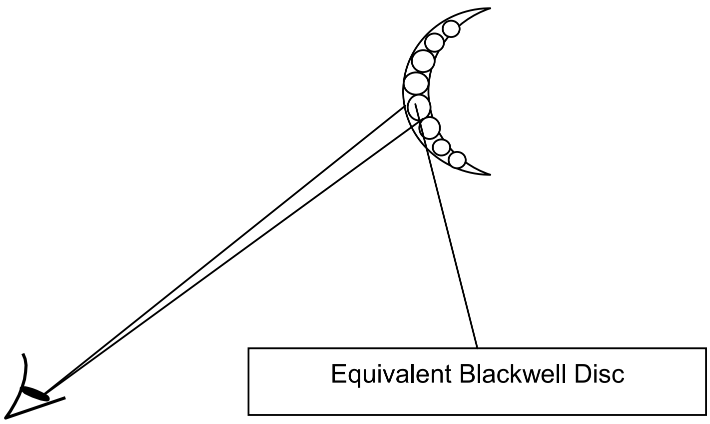

Fig. 2a: We consider the thin lunar crescent as a group of discs of varying angular size, and each has its equivalent Blackwell disc.

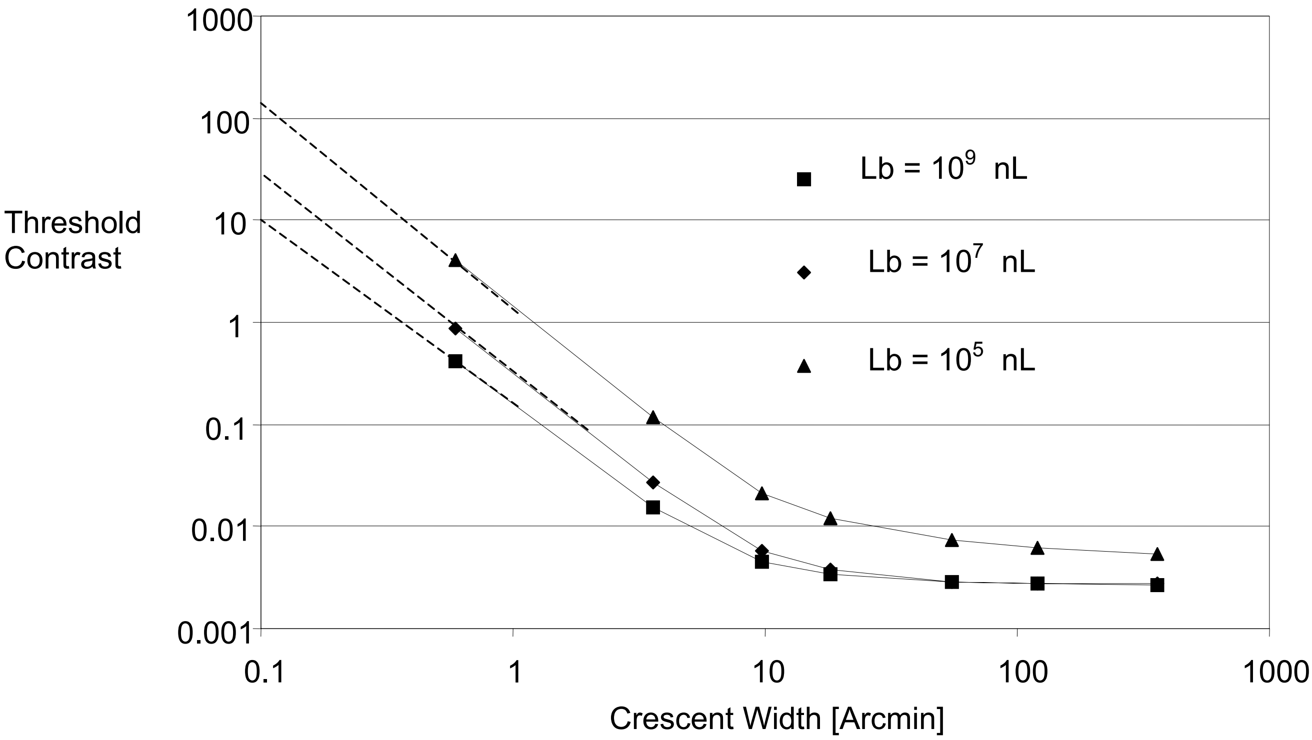

Fig. 2b: An example of our extrapolation of the data in table VIII of Blackwell (1946), the crescent width is equal to 0.1 arc minute.

To evaluate the luminance of the thin crescent moon at the moment of observation, the following equations are used:

The actual (extra-atmospheric) luminance of the moon in tenth magnitude stars per square degree (S_{10}) is given by:

$$L_* = (1/D)\ 2.51^{(10-m)} \qquad (1)$$

where D is the illuminated area[5].

The apparent (ground-observed) luminance of the moon in S_{10} will be:

$$L = L_*\ e^{-kX} \qquad (2)$$

where k is the atmospheric extinction given by Walker (1987)[6], and X is the air mass given by the Rozenberg equation[7]

$$X= (\cos (Z)+0.025e^{-11\cos(Z)})^{-1} \qquad (3)$$

and where Z is the zenith distance of the moon in degrees.

The apparent luminance in nanolamberts (nL) will be[8]:

$$L = 0.263\, L_* \, e^{-kX} \qquad (4)$$

The western sky twilight (L_B) was measured at Mouneef, Yemen (1990 metres above sea level, 44 degree E, 13 degree N). Mouneef is one of ten sites -proposed by the author and his colleague Prof. Querci of the Midi-Pyrenees Observatory in France- to install a Regional Observatory[9]. The measurements were achieved using a PHYWE selenium photocell (45-mm diameter, corrected to the human eye; calibration with metal filament lamp at 2850 degree K), Fig.3 (a). The measured data are represented in Fig.3 (b).

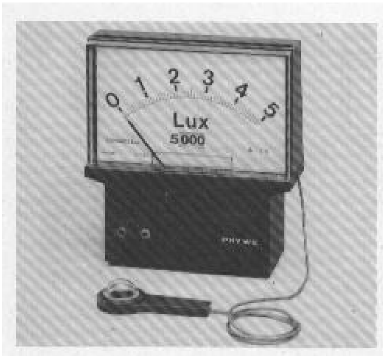

Fig. 3a: The apparatus used to measure Mouneef western sky twilight

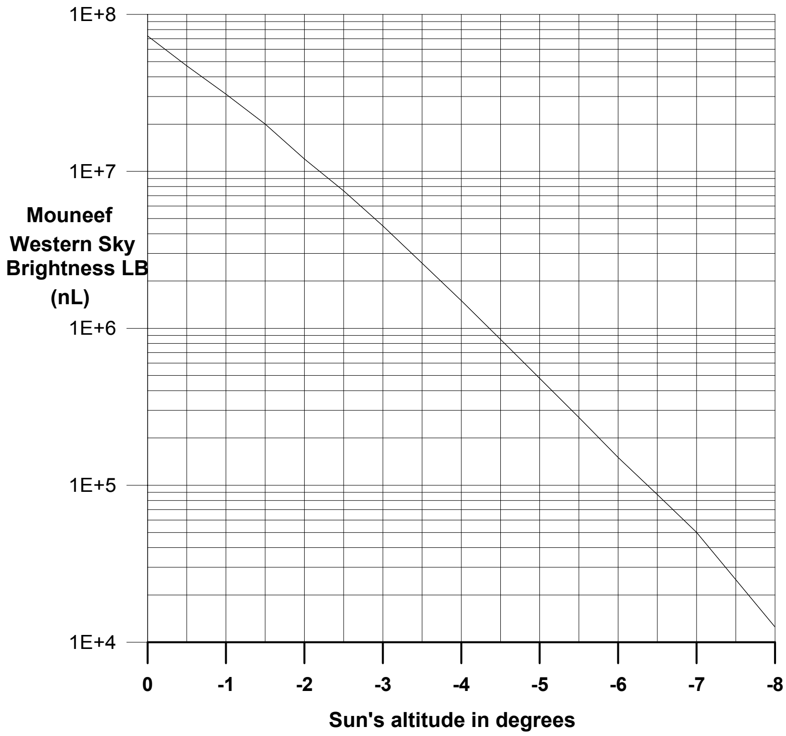

Fig. 3b: Sky luminance (in nL) as a function of sun depression (in degrees).

The contrast C between the crescent luminance L and the twilight sky luminance L_B will be:

$$C = (L - L_B)/ L_B \qquad (5)$$

Finally, visibility criterion (Vis) can be written as:

$$C > C_{th} \qquad (6)$$

- Using software of the Institut de Mécanique Céleste et de Calcul des Éphémerides (IMCC, http://www.imcce.fr) or the Multiyear Interactive Computer Almanac software (MICA, http://aa.usno.navy.mil) , one can obtain the lunar phase angle (Ph.angle), the apparent semi-diameter of the Moon (Semi-dia), the magnitude (Mag) and the illuminated fraction (Ill%). The western sky twilight (L_B) was measured. The above equations are used to calculate the actual luminance of the crescent (L_*), the apparent luminance (L), the crescent width (W) and the contrast (C). Fig. 2 b is used to obtain Blackwell's Contrast Threshold (C_{th}). The following parameters are presented in Tables I and II: α , r, Ill%, L_*, L, W, L_B, C, and C_{th}.

- From Tables I and II the smallest visible width of the crescent in two cases is obtained: when the crescent is near apogee and when it is near perigee. In these tables a site of observation with an elevation around 2000m, and with a perfect geometrical situation[†] DAZ = 0°, is considered. The optimum moon altitude at the moment of observation is considered to be 2 degrees (for Mouneef, the quotient $C_/ C_{th}$ has a maximum value at this altitude).

Date UT	h	m	Ph.angle o	Semi-dia '	Mag	% ill	L* (nl)	L (nl)	W '	LB (nl)	Cth	C	Vis C>Cth
14 3 2002	2	5	175	14.68	-4.43	0.19	4.3E8	2.4E7	0.06	1.2E7	60	1	no
14 3 2002	7	5	174.5	14.68	-4.48	0.23	3.7E8	2.1E7	0.07	7.5E6	43	2	no
14 3 2002	9	20	174	14.68	-4.54	0.27	3.4E8	1.9E7	0.08	4.5E6	41	3	no
14 3 2002	11	20	173.5	14.69	-4.6	0.32	3E8	1.7E7	0.1	2.6E6	38	6	no
14 3 2002	12	50	173	14.69	-4.65	0.37	2.7E8	1.5E7	0.11	1.5E6	33	9	no
14 3 2002	14	20	172.5	14.69	-4.7	0.42	2.5E8	1.4E7	0.12	8.5E5	31	15	no
14 3 2002	15	50	172	14.69	-4.75	0.48	2.3E8	1.3E7	0.14	4.8E5	32	26	no
14 3 2002	17	16	171.5	14.69	-4.81	0.55	2.1E8	1.2E7	0.16	2.7E5	37	43	yes
14 3 2002	18	40	171	14.69	-4.86	0.62	2E8	1.1E7	0.18	1.5E5	39	72	yes
14 3 2002	19	57	170.5	14.69	-4.92	0.68	1.9E8	1.1E7	0.2	8.7E4	43	125	yes
14 3 2002	21	12	170	14.69	-4.97	0.76	1.8E8	1E7	0.22	5E4	46	199	yes

Table I: Moon near apogee

(New Moon: Mach 14, 2002 at 02:05 UT)
(DAZ = 0°, site elevation 2000 m, Moon altitude = 2°)

[†] the difference in azimuth between the Sun and the Moon at the moment of observation is equal to zero degrees

Date UT	h	m	Ph.angle o	Semi-dia ‘	Mag	% ill	L* (nl)	L (nl)	W ‘	LB (nl)	Cth	C	Vis C>Cth
14 3 2002	2	5	175	14.68	-4.43	0.19	4.3E8	2.4E7	0.06	1.2E7	60	1	no
14 3 2002	7	5	174.5	14.68	-4.48	0.23	3.7E8	2.1E7	0.07	7.5E6	43	2	no
14 3 2002	9	20	174	14.68	-4.54	0.27	3.4E8	1.9E7	0.08	4.5E6	41	3	no
14 3 2002	11	20	173.5	14.69	-4.6	0.32	3E8	1.7E7	0.1	2.6E6	38	6	no
14 3 2002	12	50	173	14.69	-4.65	0.37	2.7E8	1.5E7	0.11	1.5E6	33	9	no
14 3 2002	14	20	172.5	14.69	-4.7	0.42	2.5E8	1.4E7	0.12	8.5E5	31	15	no
14 3 2002	15	50	172	14.69	-4.75	0.48	2.3E8	1.3E7	0.14	4.8E5	32	26	no
14 3 2002	17	16	171.5	14.69	-4.81	0.55	2.1E8	1.2E7	0.16	2.7E5	37	43	yes
14 3 2002	18	40	171	14.69	-4.86	0.62	2E8	1.1E7	0.18	1.5E5	39	72	yes
14 3 2002	19	57	170.5	14.69	-4.92	0.68	1.9E8	1.1E7	0.2	8.7E4	43	125	yes
14 3 2002	21	12	170	14.69	-4.97	0.76	1.8E8	1E7	0.22	5E4	46	199	yes

Table II: Moon near perigee

(New Moon: 23 11 2003, at 23:00 UT)
(DAZ = 0º, site elevation 2000 m, Moon altitude = 2º)

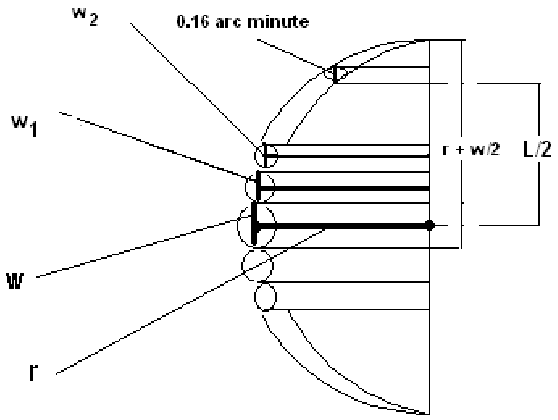

Fig. 4: Starting from the centre of the crescent and going in the direction of the cusps, the crescent contains two groups of discs, each group representing a decreasing geometric progression. The visible crescent length in degrees will be: L /2r × 180°
where L represents the vertical component of the visible crescent length in arc minutes and is given by
$L = 2r - 2w\,(r+W/2)/W - W$

Where r is the apparent semi diameter of the moon, W is the width of the crescent, and *w* is the biggest invisible width. For our site *w* = 0.14 arc minute near apogee and *w* = 0.16 arc minute near perigee (see Tables I and II).

Finally, using table I, table II, and Fig. 4, one can calculate the length of the visible crescent as follows:

On the vertical diameter of the moon disc (Fig. 4), the length of the group of discs starting with the disc at the centre and ending at the end of one cusp is equal to r + w/2

$$r + W/2 = W + W_1 + W_2 + \ldots.$$
$$= W + W[1-W/(r+W/2)] + W\,[1-W/(r+W/2)]^2 + \ldots.. \qquad (7)$$

The right side of Eq. (7) represents a decreasing geometric progression[10] whose sum is equal to: W/W/(r+W/2) = r+W/2

In Fig. 4, let L/2 be the distance starting at the centre of the moon disc and ending at the beginning of the biggest invisible width *w* (for Mouneef *w* = 0.14 arc minute near apogee and *w* = 0.16 arc minute near perigee)

$$L/2 = r - w/(r+W/2) - W/2$$
$$= r - w/W/(r+W/2) - W/2$$
$$= r - w\,(r+W/2)/W - W/2$$

then,

$$L = 2r - 2w\,(r+W/2)/W - W$$

where L represents the vertical component of the visible crescent length in arc minutes.

Then, the visible crescent length in degrees will be: L /2r × 180°

According to this model prediction, the author and his 4th year students succeeded in observing the planet Venus with the naked eye at noon on 28 April 2004. Perhaps this group was not the first to make this observation, but was certainly the first to publish that!

Conclusions

- At site elevation of around 2000m, the crescent moon can be seen with the naked eye, if its width is between 0.14 arc minute and 0.16 arc minute.

- The model introduces a method for calculating the approximate visible length of the thin crescent moon.

- The photometric model presented here produces the same results obtained by Schaefer's empirical model, but with a different interpretation concerning the cause of length shortening.

- According to the present model prediction, the author and his students succeeded in observing Venus at noon with the naked eye.

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THE IMPACT OF HISTORICAL CHINESE ASTRONOMICAL RECORDS

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Abstract

The impact of Chinese historical astronomical records is important in the study of astronomy today. In particular, the impact of the Chinese records related to historical supernovae have made important contributions to modern astronomy, owing to the rapid progress of space sciences and high-energy astrophysics made in the past two decades. These historical records could also be of assistance in the future. In this connection, the main topics discussed in this paper are the great new star, which was observed in the 14^{th} century Before Christ (BC), the historical supernovae Anno Domini (AD) 185 and AD 393, and the new concept of the "Po star" and its application.

1. Introduction

Before the Renaissance, most historical supernova (SN) records were from countries of the Orient, mostly from the People's Republic of China. Biot (1846) and Houmbolds (1850) were the pioneer Western astronomers who introduced the historical Chinese astronomical records to North America and Western Europe over 150 years ago. Since the beginning of the 20th century, an increasing number of astronomers have continuously worked on this field, such as: Zinner (1919), Lundmark (1921), Yamamoto (1921), Xi (1955), Ho (1962), Xi and Bo (1965) and Clark and Stephenson (1977), among others.

The impact of historical SN records is very important because it can provide the historical clues to the origin and evolution of supernova remnant (SNR) and neutron star (NS), providing new information to the active fields of astrophysics and physics. The best example is the famous Tian-Guan guest star with its remnant Crab Nebula (Wang, 1987a). In this paper, the author takes no account of the well-known and accepted supernovae (SNe) 1006, 1054, 1181, 1572 and 1604, but concentrates on the discussion of some probable historical SNe that have not yet been generally accepted and need to be further discussed.

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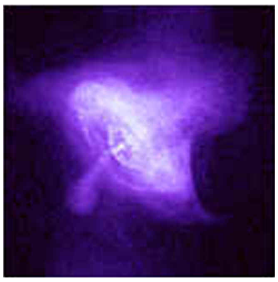
2. The Great New Star

Thus, it becomes interesting to pose the question: what is the earliest SN observed and recorded by human beings? The answer is the great new star that appeared in the 14th Century B.C. and was observed by the ancient Chinese and recorded on an oracle bone (see Fig.1) with the following inscription, extracted from the second part of the ninth chapter of Yin-Xu-Shu-Qi-Hou-Bian: "On the seventh day of the month, a Ji-Si day, a great new star appeared side by side with the Antares (α Sco)".

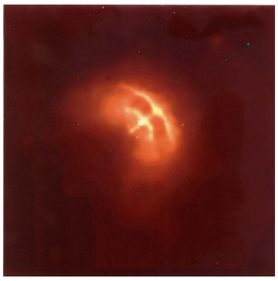
Fig.1: The great new star recorded by the ancient Chinese on the oracle bone.

Dong (1945), Xi (1955) and Needham (1959) considered the great new star as a SN. This star was probably related to the contemporary gamma ray source since it was suggested that the gamma ray source observed by the European Space Agency's COSB satellite, 2CG 353+16, might be its compact remnant (Wang, 1987 b, c) and diffuse remnant (Xu, Wang and Qu, 1992). Narike (1999) agreed with this idea and determined exactly the age of the great new star by use of the five lunar eclipses that occurred during the reign of King Wu-ding. The remnant of the great new star will surely be an important target for the future gamma ray observation.

3.The Structure of some centre-filled SNRs



a



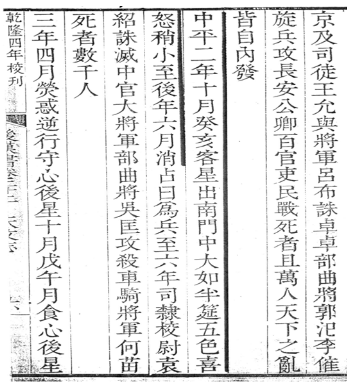
b

c

Fig. 2: Chandra images of Crab Nebula (a), Vela SNR (b) and MSH 15-52 (c)

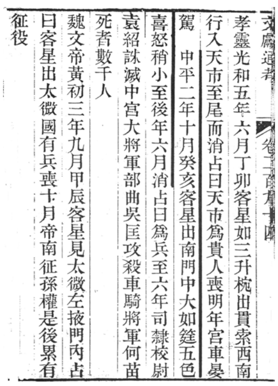
Some crab-like or centre-filled SNRs (Crab, Vela and MSH15-52) are axial symmetrical with the spinning axis of their own pulsars, as shown in their Chandra observations (Fig. 2) and as pointed out by Helfand et al. (2001) and Gaensler et al. (2002); however, such SNRs are not symmetrical with their equatorial planes. Has the nature of this general character or similarity originated from the initial explosion of a SN—the equatorial toroidal wind and a jet along the spinning axis? Can any of these traces be seen in the historical records? These are interesting questions that deserve attention.

4.AD185 Guest Star



京及司徒王允與將軍呂布誅卓卓部曲將郭汜李傕
旋兵攻長安公卿百官吏民戰死者且萬人天下之亂
皆自內發
中平二年十月癸亥客星出南門中大如半筵五色喜
怒稍小至後年六月消占曰爲兵至六年司隸校尉袁
紹誅滅中官大將軍部曲將吳匡攻殺車騎將軍何苗
死者數千人
三年四月熒惑逆行守心後星十月戊午月食心後星
乾隆四年校刊

(a)



文獻通考
孝靈光和五年六月丁卯客星如三升椀出貫索西南
行入天市至尾而消占曰天市爲貴人喪明年宮車晏
駕
中平二年十月癸亥客星出南門中大如筵五色
喜怒稍小至後年六月消占曰爲兵至六年司隸校尉
袁紹誅滅中宮大將軍部曲吳匡攻殺車騎將軍何苗
死者數千人
魏文帝黃初三年九月甲辰客星見太微左掖門內占
曰客星出太微國有兵喪十月帝南征孫權是後累有
征役

(b)

Fig. 3: The historical records of AD185 guest star: (a) from Hou Han Shu, b) from Wen–Xian Tong–Kao.

The historical records of SN 185 are shown in Fig. 3 (a) and (b) with their English translation as follows:

(a) Second year of Zong Ping reign period, tenth lunar month, day Gui-Hai (7 December, 185 AD), a guest star appeared within Nanmen. It was as large as half a yan (筵). Its multicolours were scintillating. It gradually became smaller and in the sixth lunar month of the following year it vanished.

(b) Second year of Zong Ping reign period, tenth lunar month, day Gui-Hai (7 December, 185 AD), a guest star appeared within Nanmen. It was as large as Ting (筳). Its multicolours were scintillating. It gradually became smaller and in the sixth lunar month of the following year it vanished.

Although Clark and Stephenson (1977) suggested G315.4-2.3 (RCW 86) to be the remnant of SN 185, the question of which SNR is to be associated with SN 185 still has to be further discussed. Bocchino et al. (2000) pointed out that "most distance estimates either assume that RCW86 is SN 185 or imply a distance much larger than 2 kpc" and "for RCW 86 to be the remnant of SN 185, it has to be closer than 2 kpc (Pisarski et al., 1984)". In fact, Bocchino et al. (2000) could not avoid the same problem. They assumed a set of explosion of energy to fit the age of SN 185 (see Table 7 in Bocchino et al. 2000), rather than using the known value of its distance or neutral hydrogen column density to do the analysis as usual.

Thorsett (1992) suggested SNR MSH15-52 and its central pulsar 1509-58 with a spin down age of 1.7 thousand years to be the remnant of SN 185. That may be a favourable suggestion. However, little difference between the two records (Fig. 3 (a) and (b)) deserves to be mentioned. It has been commonly thought that this was due to the rewriting error in the record from Wen-Xian Tong-Kao. One cannot, however, rule out another possibility: that both records are real. The description (a) means half a mat and (b) means a little piece of bamboo. If one considers that both records are real, what would happen then? Is it possible that 'half a mat' perhaps refers to the equatorial toroidal wind or something just like the Napoleon's Hat in SN 1987A (Wang and Wampler, 1996) and that 'little piece of bamboo' refers to a jet? If SN 185 is a usual SN, then surely one cannot see these phenomena during its explosion. MSH15-52 is indeed a very special and energetic SNR (Gaensler et al. 2002 and references therein). Let us assume that MSH15-52 is the remnant of SN 185, considering that its distance is around 5 kpc (Gaensler et al. 2002). Even then, SN 185 had been visible for more than one and a half years as the records mentioned above, it is still difficult to have the space resolution for the records of Fig. (a) and (b) observed by naked eyes. Perhaps SN 185 needs to be an unusually nearby SN, hypernova or gamma ray burst if records (a) and (b) are real, otherwise a great challenge has to be put forward to modern physics and astrophysics for the speed limit of light.

5. AD393—G347.3-0.5 (RXJ1713.7-3946)

SNR G347.3-0.5 at Scorpius constellation was discovered by Röntgen Satellite (ROSAT) (Pfeffermann and Aschenbach, 1996). It was suggested (Wang, Qu and Chen, 1997) that SNR G347.3-0.5 was the remnant of AD393 guest star on the basis of the principal of four dimension identification (Wang et al., 1986). The historical record of AD393 guest star is as follows: "A guest star appeared within the asterism Wei during the second lunar month of the 18^{th} year of the Tai-Yuan reign period (27 February to 28 March, 393 AD), and disappeared during the ninth lunar month (22 October to 19 November, 393 AD)", extracted from Song Shu.

Clark and Stephenson (1977) conducted a very detailed investigation on the possible remnants of SN 393. They first listed seven SNRs within Wei, then eliminated five of them and suggested CTB 37A(G38.5+0.1) and CTB 37B (G38.7+0.3) as possible remnants of SN 393. But the distance of both SNRs is approximately 10.2±3.5kpc. It is difficult for a SN at the Galactic plane as far as ~10kpc to be visible on Earth by naked eyes for a period of eight months. In fact, it was not possible for Clark and Stephenson (1977) to give the same explanation as the author's nearly 10 years before the discovery of SNR G347.3-0.5.

The author's identification of G347.3-0.5 as the remnant of AD393 guest star was first criticized by Slane et al. (1999). They considered the remnant to be distant (6 kpc) in a carbon monoxide (CO) cloud, and of moderate age. Recently, Fukui et al. (2003) used the 4-metre telescope equipped with the most sensitive superconducting mixer receiver to observe 1.1 million positions in CO emission for the most extensive CO dataset and discovered the interacting molecular gas toward the Tev gamma ray peak of the SNR G347.3-0.5. They pointed out that "G347.3-0.5 is strongly interacting with the CO molecular gas at a distance of 1 kpc, but not with a distant cloud as previously favoured. This is consistent with the Tev gamma ray distribution, which shows a peak just towards the CO peak." and "G347.3-0.5 is considered to be a young SNR explored in a low density cavity (~0.01 cm-3)." The recent column density of HI and CO observation also supports that G347.3-0.5 is at a distance of 1kpc (Koo 2004).

To summarize, the millimetre observation and Tev gamma ray observation towards the SNR G347.3-0.5, as well as the column density of HI and CO observation strongly support the identification of G347.3-0.5 as the remnant of AD393 guest star.

6. Concerning the "Po Star"

People have usually considered the bright suspected new star with visible duration of longer than six months as suggested by Clark and Stephenson (1977) as a necessary condition for SNe to be certainly applicable only for nearby SNe. One would expect distant SNe to be faint and shortly visible. There are many appellations for the ancient suspected new stars: guest star, strange star, broom star, “Po star”, etc. The most complicated one among such stars is the “Po star”. “Po star” is a term that was usually used to describe a faint comet or a comet just during its faint phase. Thus, a “Po star” looked like a very weak comet in visual magnitude, usually without a tail if no other additional notations were found. Ancient people could discover new faint point sources never seen before; however, they could not distinguish their nature. This is the reason why the concept of a “Po star” came about (Wang, Li and Zhao, 2002).

Today, a “Po star” can be considered as a faint point source around the visual magnitude of 5. There are about one hundred “Po stars” recorded from 2320 BC up to the beginning of the 20^{th} century. Xi and Bo (1965) suggested seven criteria to distinguish SNe or novae from such stars. The main standard generally accepted is that the object had to be non-moving and without tails. Between 20 to 30 “Po Stars” are proposed to be candidates for SNe or novae (Xi and Bo, 1965; Chen, 1986). Based on the author’s new concept of “Po star”, the SGR 1900+14 (Hurley, 1999) and the youngest PSR J1846-0258 (Gotthelf et al. 2000) are suggested to be the remnant of the 4 BC “Po star” and 1523 AD “Po star”, respectively (Wang, Li and Zhao, 2002; Wang, 2001).

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THE BASIC SPACE SCIENCE INITIATIVE: CAPACITY BUILDING IN DEVELOPING COUNTRIES

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1. Basic space science

1.1 Introduction

Astronomy and basic space science are both areas that have developed rapidly in recent years. Unfortunately, although a large number of countries have made efforts to benefit from such rapid progress in science and technology, a large number of countries around the world continue to lack the human, technical and financial resources to conduct even the most basic of activities within the field; for example, the operation of small astronomical telescopes.

Since the inception of the United Nations Programme on Space Applications, a continuous effort has been made by the United Nations Office for Outer Space Affairs in furthering the knowledge and experience of space applications around the world. Provision of in-country capacity-building, education, research and development support and technical advisory services by the Programme have all helped to create conditions under which the developing countries have started to benefit from their involvement with the Basic Space Science activities.

The workshops take place on a regional basis, namely in Asia and the Pacific, Latin America and the Caribbean, Africa, Western Asian and Europe. It is imperative for support to be received from the Member States, under the auspices of the UN Programme on Space Applications in order to ensure the success of these workshops. Hosting the Basic Space Science workshops in the various regions allows the United Nations and the European Space Agency (ESA) to develop a factual focus relevant to each region.

1.2 Implementation Process: Tripod

An extremely effective method of implementation, known as 'Tripod', developed as a result of the workshops on Basic Space Science, identifies three key factors that are needed in order develop a strong education system in developing countries:

1. The availability of research tools allowing meaningful science to be conducted;
2. Teaching materials allowing basic space science to be introduced at the teaching level of fundamental mathematics, physics and chemistry courses in middle-level and higher education; and

3. Application material for original research in basic space science such as observing programmes for variable stars[1]

The Tripodial approach has already had quite an impact on the educational system and working conditions for some established researchers based in developing countries. Soon, a fourth leg may be added to the Tripodial implementation process via the introduction and availability of data archives from space missions. If communication to and from developing countries were to be developed, the availability of the 'Virtual Observatory' concept would prove to be a valuable contribution to research and education.

2. Region-by-region Analyses of Basic Space Science Facilities

A short description shall be provided in this chapter of Member States and their status and level of activity within the space sector. The information provided in this section is a summary of the data that the UNOOSA Basic Space Science initiative currently possesses on each Member State. Ideally, in order for countries to benefit from the Basic Space Science Initiative, the aforementioned records must be kept up-to-date.

2.1 Asia and the Pacific

Malaysia

Dr. Mazlan Othman is the founder of the National Space Agency of Malaysia, whose huge efforts have resulted in an increased awareness of the importance of space applications to the country. A Coupe telescope from Zeiss Jena was purchased by Malaysia. Unfortunately, the telescope experienced several technical problems that required some time to repair, as the original manufacturers had to be contacted in order to mend the problems. Therefore, adequate training must be provided to all countries that a telescope is donated or sold to, in order to ensure maximum results in research and education efforts.

The Philippines

Current activities in astronomical education and research within the Philippines are limited in scope.[2] Astronomy is taught as part of a general science subject in elementary school and is offered as an elective subject, during one semester in the first year of high school. At college level, there is only one university that offers the topic of astrophysics to students who are enrolled in a course in physics. One other university offers training courses in applied geodesy, which contains basic and advanced subjects in remote sensing.

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[1] 'Tripod Implementation at Vanderbilt University', Rexroth R., Vanderbilt University.

[2] The necessity of a high-grade telescope for education and future research activities in the Philippines, Ms. Cynthia P. Celebre, Philippine Atmospheric, Geophysical and Astronomical Services Administration (PAGASA), Department of Science and Technology (DOST)

The Philippine Atmospheric, Geophysical and Astronomical Services Administration (PAGASA) conducts regular information, education and communications (IEC) activities to promote astronomy in the Philippines. The research activities of PAGASA are primarily devoted to data collection on astronomical phenomena. The data are sent to international astronomical centres and consolidated with other global observations. Astronomical almanacs, circulars and other information are, in return, received from these centres regularly, and form the basis for the computation and publication of astronomical data and information for local users.

The astronomical activities in PAGASA, however, are performed by personnel who do not have any formal education in astronomy. The knowledge in astronomy that they possess is obtained through the in-service training courses, which are infrequently conducted by the agency and through the books and publications that are usually procured from overseas sources. Only a few personnel are sent abroad to attend related workshops, seminars and training courses (for example, the post-graduate course on remote sensing at the Regional Centre for Space Science and Technology Education in Asia and the Pacific, affiliated to the United Nations, in India). In 2001, the Japanese Government donated a 45 cm, computer-based astronomical telescope to the Philippines. This telescope is located at the PAGASA Astronomical Observatory inside the campus of the University of the Philippines.

Viet Nam

It was noted that Viet Nam had no planetarium in order to provide general education in astronomy and space science.[3] A proposal was made to Japan to donate a planetarium under the Japanese Cultural Grant Aid scheme. This proposal was accepted and the planetarium was built.

Republic of Korea

The Nha Il-Seong Museum of Astronomy was founded in 1998 and opened in October 1999. The museum's aims are to exhibit the astronomical works that are available in the Republic of Korea, China, Japan and other countries of the Far East. Furthermore, the museum intends to serve the public with written material for the study of the history of oriental astronomy as well as operate a 40 cm reflecting telescope in order to compliment the research of both professional and amateur astronomers.

Mongolia

An application was made by Mongolia to the Government of Japan for an astronomical telescope. The following attributes were highlighted with regard to the installation of the facility in Mongolia:

- Climate is comparable to that of Kitt Peak with 250 clear nights per year;
- The longitude for astronomy would fill the gap between Hawaii and Europe;

[3] Letter, 12th September 1994, noting lack of planetarium in Vietnam, from M. Kitamura, Professor Emeritus of University of Tokyo

- Mongolian observatory has 20 astronomers, seven with doctoral degrees from Russian universities;
- The infrastructure of the observatory is good; and
- If a telescope could be found, the Mongolian government would most probably provide the building and the dome.

2.2 Latin America and the Caribbean

Paraguay

The Japanese Government, under its Cultural Grant Aid programme, donated a 45-cm Cassegrain telescope to Paraguay in 1999. Prior to this donation, Paraguay lacked an astronomical facility and was therefore unable to conduct outreach activities involving astronomy and celestial mechanics.

Brazil

The Southern Space Observatory (SSO) is located at Sao Martinho da Serra and already maintains several scientific instruments monitoring space weather parametres, thus contributing to vigorous research in the general area of space weather studies. SSO is operated by the Southern Regional Center of Space Research (CRSPE) of the National Institute for Space Research. There were plans for a small optical telescope to be installed at SSO, in order to encourage university students to acquaint themselves with astronomy and astrophysics and lead them to advanced level research in the field of Radio Astronomy. In addition, SSO plans to develop a large radio telescope in the coming years.

Peru

The observatory at Cosmos was completely destroyed by a terrorist attack on 31 October 1998. [4] After this attack, there remained various solar observation equipment. Two 15 cm aperture refractor telescopes were donated by the Government of Japan and were installed at the observatory in Paracas. In 2001, Peru expressed an interest in the installation of virtual observatories.

Bolivia

The Max Schreir Planetarium of the Universidad Mayor de San Andrés (UMSA) is the only planetarium in Bolivia available for use by students and the general public. The planetarium is of modest size (seats 40 people) and unfortunately, contains outdated equipment. In order to retain the interest of students who continually go to see presentations, it is advisable to replace that equipment. This problem prompted Bolivia to seek help from institutions. In addition, an application was made for a donation from the cultural Grant Aid of the Japanese Government for a new planetarium and other complementary equipment.

[4] Construction Draft of the 'National Astronomical Observatory of Japan' by Mutsumi Ishitsuka K., Instituto Geofisico del Peru, Ministerio de Educacion, Peru

Two institutions in Bolivia carry out activities in the field of Space Science: The National Academy of Science of Bolivia and UMSA. The latter has research fields that mainly focus on the laboratory of cosmic physics. In addition, UMSA undertook the INCA project, which focused on the search for Gamma Ray Bursts. The area of Theoretical Physics (Astrophysics) is a recent creation and looks at:

- The evolution of the rate of stellar formation;
- Chaos in Cosmology; and
- Thermodynamics and Statistics of black holes

In the field of Space Science, UMSA looks at the Astrometry of Minor Bodies. In addition to diffusion activities and education, the Max Schreier Planetarium carries out other studies, these include registration of solar activity; meteorites and meteorite craters; and cultural astronomy.

Uruguay

A proposal was made by Uruguay in 1996 for the implementation of a remotely controlled robotic astronomical telescope. This telescope would be entirely remotely controlled by computers from any place in the world via the Internet and available for research in education centres or even private homes. The opening of the telescope, the positioning of the instrument and the shooting of images would be automatically performed in answer to the requests made from distant areas or according to a predetermined routine. The images obtained would be sent to the requesting party and simultaneously incorporated to a data base available to all system users.

A few examples for observation campaigns are as follows:

- Study of variable stars (especially semi-regular cataclysmic stars);
- the search for novas and supernovas in other galaxies;
- follow-up asteroids and comets; and
- other less 'classic' objects, adequate for small telescope observation.

Such a project would promote international cooperation and strengthen astronomy teaching in Uruguay, especially at the high school level; however, the aforementioned proposal has not yet been implemented.

2.3 Africa

Uganda

Interest has been shown by Uganda in the setting up of a planetarium; however, before such a project can be implemented, further information is required regarding the equipment, teaching facilities and material currently available in the country.

Ghana

Ghana made a request for a moderate-sized optical telescope to be installed at the University of Science and Technology in Kumasi, Ghana,[5] in order to acquire effective teaching and research in basic space science and astronomy[6]. As a follow-up project to the UN/ESA series of workshops on basic space science, the country would like to introduce basic space science and astronomy as a general and compulsory course of study for all science and engineering students. The University is also willing to organize regional seminars, workshops and conferences on basic space science for the benefit of teachers, scientists, students and the general public. Ghana is keen on establishing such facilities so that motivated students are encouraged to pursue research in this area.

Morocco

A workshop on 'astronomical site evaluation in the visible and radio range' took place in November, 2002, in Marrakech, Morocco. Morocco expressed a strong interest in applying for a telescope under the Japanese Cultural Aid Scheme.

2.4 Western Asia

Pakistan

An application was made by Pakistan to the Government of Japan for the donation of an optical telescope. It was decided that the best place to house the telescope would be at the University of Karachi. The university already houses a small astronomical observatory and has established the Institute of Space and Planetary Astrophysics, which enrolled MPhil and PhD students to carry out their research in the various areas of space science. In order to initiate any serious observational programmes, however, a research grade telescope is required.

Syrian Arab Republic

A request was made to the Government of Japan for the donation of a telescope, so as to achieve the establishment of a Syrian National Observatory.

Bahrain

Interest has been expressed in hosting a UN/ESA Workshop on Basic Space Science; however, as workshops have been reserved for the next five years, it is difficult to foresee when this would take place.

Yemen

Yemen made an application to the Japanese Cultural Grant Aid programme for the installation of an astronomical instrument.[7]

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[5] July 1995

[6] Proposal for Moderate-sized optical telescope for University of Science and technology, kumasi, Ghana, department of physics.

[7] 16th June 2004

2.5 Europe

Romania

It appears that Romania was the only country in Europe to have no modern planetarium for astronomical education. An application was made to the Japanese Cultural Grant Aid for a planetarium project in Bucharest.

3. The survey

3.1 Goals and Structure

In order to determine the status of astronomical facilities and education curricula in developing countries, it was decided that a survey be carried out by the Basic Science Initiative of the UN Office for Outer Space Affairs. The survey would focus on the availability, quality and location of astronomical facilities and education curricula (astronomy and celestial mechanics). The survey and cover letter sent are shown in the next few pages.

There is still a great deal that is not known regarding the status of astronomical facilities and education curricula in developing countries. The Office for Outer Space Affairs has made extensive efforts since the beginning of the Basic Space Science Initiative to collect data on those facilities from as many Member States as possible. The focus of this effort is clearly on developing countries, as it is necessary to know which facilities are lacking in order to determine what is needed; however, the survey was also sent to developed countries. The ultimate goal of the survey is to create an international catalogue that would be continually updated, containing information on the astronomical research facilities and education curricula (in the fields of astronomy and celestial mechanics) available in each of the Member States. In addition, the catalogue would provide a means for comparing the facilities available in developed countries to those in developing countries, thus highlighting improvements that need to be made in the developing Member States.

A database of scientists who have taken part in the Basic Space Science workshops has been compiled and updated by the Office for Outer Space Affairs since the Initiative was initiated. The database consists of approximately 2,000 members, thus providing a valuable asset to the Basic Space Science Initiative as a whole. In addition, the database provides an excellent means of communication between all scientists on an international level. There are many advantages to having such an extensive communication base, for example, such a database allows scientists from developing countries to contact scientists from industrialized countries and vice versa, thus increasing international cooperation and diversifying research.

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22 June 2004

Dear Sir/Madam

Since 1991, the United Nations Office for Outer Space Affairs (UNOOSA), through its Programme on Space Applications, and the European Space Agency have been coordinating the regional and international workshops on Basic Space Science. As a follow up to these workshops UNOOSA is currently carrying out a survey of the Member States that have not yet fully participated in and benefited from the aforementioned workshops. Selected information on the workshops can be found at: http://www.oosa.unvienna.org/SAP/bss/index.html

This survey is being conducted, as it is inherent that we know what facilities are available in each country in terms of astronomical observatories and educational curricula at university level (i.e. astronomy, physics, celestial mechanics). This then enables us to design the workshops so as to suit the interests of all countries involved, thus ensuring that each country achieves the maximum benefit from participating and contributing to these workshops.

Provision of in-country capacity building, interaction between scientists and engineers on a global level, education, research and development support and technical advisory services by the Programme on Space Applications have all helped to create conditions under which the developing countries have started to benefit also from progress made in basic space science by the – at the time – still small number of developed countries actively involved in this field of research and education.

It would be greatly appreciated if you could fill out the questionnaire that has been attached to this email. This questionnaire will provide us with sufficient information so as to encourage participation from countries that are still in the fields of infancy in terms of astronomy and astrophysics.

I look forward to your reply.

Kindest Regards

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SURVEY

As part of the UN Basic Space Science initiative, this survey is being conducted on an international scale and will inform the Office for Outer Space Affairs (OOSA) about the availability of facilities in developing countries in terms of astronomical observatories and education curricula at university level. This survey will allow the Office to design workshops so as to suit the interests of all countries involved, thus ensuring maximum benefit on the part of workshop attendees. Your help with this survey is very greatly appreciated and we look forward to hearing from you.

1)	Are there any research-level astronomical observatories in your country? **Yes** ☐ **No** ☐		
2)	Please specify the types of telescope that are present within these observatories: **Optical** ☐ **Radio** ☐ **Both** ☐		
3)	If possible, please state the latitude and longitude of these instruments:		
	Latitude:		
	Longitude:		
4)	Where are the observatories located?		
	a)	In/near a city or town?	**Yes** ☐ **No** ☐
		If yes, please specify the town:	
	b)	In a remote location e.g. high on a mountain?	**Yes** ☐ **No** ☐
		If yes, please specify the exact location:	

OPTICAL TELESCOPES

5)	Is there a CCD attached to the telescope? **Yes** ☐ **No** ☐	
6)	What is the diametre of the telescopes' mirror or lens?	
	☐	**Less than half a metre**
	☐	**In between half a metre and 1 metre**
	☐	**Bigger than 1 metre**

RADIO TELESCOPES

7)	What is the resolution of the telescope?
8)	What is the diametre of the radio dish(es)?

9)	It would be greatly appreciated if the names, locations and contact details of these facilities were noted in the table below:

Observatory Name			
Observatory Address			
Name Of Contact			
Telephone		**Email**	
Website			
Observatory Name			
Observatory Address			
Name Of Contact			
Telephone		**Email**	
Website			
Observatory Name			
Observatory Address			
Name Of Contact			
Telephone		**Email**	
Website			

10)	If it is possible, please provide information on how these observatories are funded:	
	☐	**State-funded**
	☐	**Privately-funded**
		Other (please specify)**:**
11)	Are there any planetaria in your country? If so, please list the name, address, telephone number, email and, if possible, approximate capacity of each planetarium and the type of projector, in the table below.	

Name			
Address			
Telephone		**Email**	
Telephone			
Approximate Capacity			
Type of Projector			

Name			
Address			
Telephone		**Email**	
Telephone			
Approximate Capacity			
Type of Projector			

Name			
Address			
Telephone		**Email**	
Telephone			
Approximate Capacity			
Type of Projector			

12)	Have astronomy and celestial mechanics been incorporated into university physics curricula in your country? **Yes** ☐ **No** ☐
13)	If so, would your institution be interested in the further development of such education curricula as available at: http://www.oosa.unvienna.org/SAP/centers/centers.html **Yes** ☐ **No** ☐
14)	It would be greatly appreciated if the names of these universities were noted below and any relevant contact information for resident faculty within the university itself included:

University Name			
University Address			
Name Of Contact			
Telephone		**Email**	
Website			
University Name			
University Address			
Name Of Contact			
Telephone		**Email**	
Website			

University Name			
University Address			
Name Of Contact			
Telephone		**Email**	
Website			

If there is any additional information that you would like to attach to this survey, please do not hesitate to do so.

3.2 Results

Responses to the survey are still being received; therefore a complete analysis cannot yet be conducted. Instead, a study of what has been received so far shall be carried out.

A basic summary of the results received so far are displayed below:

COUNTRY/ ORG.	TYPE OF TELESCOPE (No. of telescopes)	DIAMETRE (MIRROR/LENS/DISH)	PLANETERIUM (No. of planetariums)	INCORPORATION OF ASTRONOMY AND CELESTIAL MECHANICS IN CURRICULA?
Russian Federation	Optical (3)	x>1	No	Yes and would like further information in this area
Poland	Questionnaire designated for observing astronomers, recipient was a planetary scientist, therefore unable to provide further information.			
Taiwan	Optical (1)	0.5<x<1	Yes (1)	Yes and would like further information
Mongolia	Optical (1)	x<0.5	No	Yes and would like further information
Ethiopia	No research level observatory in Ethiopia. In terms of education curricula, there are no celestial mechanics courses, but some astrophysics courses. An address for the astrophysics course was provided.			
Morocco	University professor, runs astronomy club and teaches a course on celestial mechanics and astro-dynamics			
Sweden	Radio (2) – one at Onsala and one at Chile	At Onsala: x>1 At Chile: x>1	Yes (1)	Yes and would like further information
South Africa	Both (three locations, multiple telescopes at each)	Optical: one with a diameter less than half a metre, one with diameter in between half and 1 metre and one with bigger than 1 metre. Radio: x>1 (26m)	Yes (2)	Yes and would like further information

European Centre for Space Law (ECSL)	Not conducting scientific experiments; however still interested in legal aspects of these researchers like the protection of the 'dark sky', access to and the use of data, for a legal environment allowing scientific researchers by all states irrespective of the degree of their development.			
Mauritius	Radio		Plans to set one up at the Rajiv Gandhi Science Centre (RGSC).	Yes and would like further information
UK	Contact Royal Astronomical Society who will inform on status of astronomy in the UK			
UK (2)	Contact National Space Centre in Leicester for information and a contact was provided for the Royal Observatory Greenwich.			
Viet Nam	Optical (1) No CCD attached so difficult to do research	x<0.5	Yes (1)	Yes and would like further information
Viet Nam (2)	Optical (1)	x<0.5	Yes (1)	Yes and would like further information
Romania	Optical (3) Locations: Bucharest, Cluj and Timisoara	Diameters are either less than half a metre or between half and metre and 1 metre	Yes (3)	Yes and would like further information
Guatemala	No research level observatories available		No	Yes and would like further information
Egypt	Optical (1)	x<0.5	Yes (1)	Yes and would like further information
Libya	Optical (1) – mobile	x<0.5	No	Yes and would like further information
Latvia	Both	x>1		
Malawi	No research level observatory available		No	No and would like further information
Fiji	Optical (1)	x<0.5	No	No and would like further information
Moldova	Optical (1)	x<0.5	No	Yes and would like further information
Jordan	Optical (1)	0.5<x<1	No	No and would like further information
Zambia	No research level observatories available		No	No and would like further information

Table 1: Member States and organizations that have responded so far.

3.3 Feedback, analysis and difficulties

As stated earlier, the survey was sent to around 2,000 recipients, all who have been part of the Basic Space Science initiative. Whilst the majority of recipients are able to provide at least some information on the astronomical facilities available within their country, there are still some cases where this information may be difficult to obtain.

Looking at Table 1, it can clearly be seen how countries like Ethiopia are lacking in both education (celestial mechanics/astrophysics) and astronomical facilities. Countries such as Ethiopia are the countries that need priority attention from both the

Office for Outer Space Affairs and the industrialized countries. It is hoped that once the majority of responses have been received for this survey, the Office as well as the industrialized countries shall be able to quickly and efficiently identify topics as priority thematic areas. As stated earlier in the report, the aim of this study is to provide a catalogue that shall be accessible to all Member States in order to observe the status of Basic Space Science within those Member States.

In order for any country to start realizing the benefits of space applications, relevant facilities must first be put in place. Regarding Basic Space Science, such facilities are the research-level telescopes and education curricula in the areas of celestial mechanics and astronomy. Before any assistance can be provided to these countries, one must have a good knowledge of the current status of the Member State in the field of Basic Space Science.

Although the focus of the survey was on developing countries, the Office for Outer Space Affairs would still like all recipient countries to reply. It can be seen that the information received and catalogued from these surveys holds many benefits. All up-to-date information, concerning the status of astronomical facilities on a global scale, will be contained in one document.

Although the survey has already been sent out, the author believes that the response-rate could still greatly improve if the survey were to be translated into the six official languages of the UN. Such a move would prove to be extremely valuable, as not only would there be an increased response-rate, but increased recognition would also be received by the Office for Outer Space Affairs from Member States for its efforts in developing Basic Space Science capabilities in developing countries.

4. Conclusions and recommendations

From the above, one can note the numerous donations made by the Japanese Government in terms of astronomical facilities (both planetariums and telescopes)[8]. Again, it is anticipated that other Member States have taken note of such actions and will make similar moves in terms of helping developing countries acquire and develop their own capabilities.

It can clearly be seen that this effort, which has been initiated by the United Nations, is in essence a large task. All data received shall be catalogued with the existing information that the Office for Outer Space Affairs maintains on particular countries.

The international catalogue containing details on the astronomical facilities and education curricula in all Member States will be unique in scope and possibly the only one known to exist. Member States will be informed of this document, with the eventual aim of establishing a protocol where any Member State that wishes to obtain information

[8] Masatoshi K., 'Aiding Astronomy in developing nations: Japanese ODA', National Astronomical Observatory, Mitaka,, Tokyo; Science Direct, Space Policy 20 (2004) 131-135

regarding another State's facilities, will be able to find the most up-to-date information within this catalogue. It must be noted that such a catalogue will have to be continually updated and therefore, Member States will have to keep the Office for Outer Space Affairs informed on the status of their facilities and research.

THE APPLICABILITY OF SPACE LAW PRINCIPLES TO BASIC SPACE SCIENCE: AN UPDATE

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I. Introduction

Outer space does not at first blush seem a likely province for lawyers; however, as with all areas of human endeavour, as soon as people begin to explore a new territory then rules are needed. These rules provide a regulatory framework for the activities of actors in space.

The corpus of space law has grown rapidly since the launch of the first artificial satellite Sputnik I in 1957. Today, space lawyers speak of a two-tiered system of space regulation. The main overarching principles are provided by international space law, in particular the five main 'space treaties' developed by the United Nations through the Committee for the Peaceful Uses of Outer Space (COPUOS). Resolutions adopted by the General Assembly are also possible sources of international custom. In addition, it is important to recognize the significance of international co-operative agreements concluded between States and/or space organizations (such as the agreement to build the International Space Station), and the contribution of regulations made by bodies such as the International Telecommunication Union (ITU), European Space Agency (ESA), United Nations Educational, Scientific and Cultural Organization (UNESCO), International Civil Aviation Organization (ICAO), Committee on Space Research (COSPAR) and others. On the second level are laws introduced by national legislatures. These may regulate domestic aspects of space activities or implement international obligations at the national level.

Space science was at the origin of humankind's drive into space. While it was advances in rocket technology, driven by military imperatives, that made space activities feasible from the very beginning of the 'space age', the scientific benefits to be accrued through the exploration and use of outer space were among the main justifications for the huge investment being made by States.[1] The International Astronautical Federation (IAF) was vocal in its support for space satellites since its founding in 1951. The International Geophysical Year (IGY) of 1957 led to the development of the US space satellite programme,[2] the establishment of the National Aeronautics and Space Administration (NASA), and was a major catalyst behind the launch of Sputnik I. Space science has continued to be for many countries the initial

[1] Gabriel Lafferranderie, 'Space Science and Space Law' in Gabriel Lafferranderie (ed), *Outlook on Space Law over the Next 30 Years* (1997) 107, 107.
[2] National Academy of Sciences, 'The International Geophysical Year 1957-1958' (2004) <http://www.nas.edu/history/igy/> (at 22 November 2004).

point of contact with space activities.[3] Given the centrality of space science to space activities, it is not surprising that it intersects with those rules made to govern space activities, that is, with principles of space law.

Astronomy and basic space science are affected by legal norms in several ways. Firstly, there may be restrictions on the types of experiments that may be conducted. Secondly, they address issues relating to the construction and launch of satellites, whether for scientific purposes or otherwise. Thirdly, there are issues of international co-operation in the conduct of space research. Fourthly, rules are required to maintain the sustainability of the space environment to ensure the future of space science.

This paper will examine the applicability of space law principles to astronomy and space science, updating the work of Winkler[4] and Lafferranderie[5] in light of recent legal developments. It will also discuss future challenges and directions of space law.

II. Space law: an overview

A. Structural regulatory framework - COPUOS

The area of space law is a paradigm example of legal drafting through international consultation. The United Nations has established itself as the central forum for consultations between States and the key mechanism for achieving legal reform.

After the first artificial satellite was launched into space in 1957, it quickly became clear that the exploration of outer space, for all its boundless possibilities for humankind, was also susceptible to becoming the latest arena in the continuation of Cold War tensions. Clearly, it was desirable to set up a framework of rules to ensure that space exploration was undertaken in the spirit of scientific endeavour, rather than for military purposes. To this end, the United Nations established the Committee for the Peaceful Uses of Outer Space (COPUOS) as an ad hoc body in 1958. One year later, it was converted into a permanent organ of the United Nations General Assembly. COPUOS is the primary body for all space-related programmes undertaken by the United Nations. It currently has 67 Member States, and consists of two subsidiary bodies: the Legal Subcommittee (LSC) and the Scientific and Technical Subcommittee (STSC).

The operation of COPUOS is typical for a United Nations body. Firstly, the STSC meets every year for two weeks in February to discuss scientific issues and develop technical expertise. On the basis of these deliberations, the LSC meets in

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[3] Kai-Uwe Schrogl, 'Basic Space Science in a Future COPUOS – Emphasizing the Role of Developing Countries' (1996), Paper presented at UN/ESA Workshop on Basic Space Science (9-13 September 1996, Bonn, Germany), 2 < http://www.seas.columbia.edu/~ah297/un-esa/paper-schrogl.html> (at 22 November 2004).

[4] Louis Winkler, 'Legal Aspects of Astronomy' (1990) 54 *Griffith Observer* 8 <http://www.seas.columbia.edu/~ah297/un-esa/paper-winkler.html> (at 22 November 2004).

[5] G Lafferranderie, 'Space Law Relevant to Astronomy' (1996), Paper presented at UN/ESA Workshop on Basic Space Science (9-13 September 1996, Bonn, Germany) <http://www.seas.columbia.edu/~ah297/un-esa/paper-lafferanderie.html> (at 22 November 2004).

March/April to develop suggestions for regulatory reform. Finally, the whole Committee meets in June to consider the work of the Subcommittees and to adopt resolutions if required. In theory, this produces a conveyor-belt approach to law reform, beginning with specialist discussion in the technical forum, leading to legal drafting, which is then adopted according to political exigencies in the full Committee.[6]

Not part of the formal decision-making process, but nevertheless equally important, are the informal discussions between delegations that take place before and during the sessions. For example, in the early stages of COPUOS, the most important decisions were made through bilateral negotiations between the USA and the former Soviet Union, as the two sole space powers.[7] Later, during the 1970s and 1980s, the so-called 'New World Order' redistribution debate led to the formation of discrete, identifiable North and South blocs.[8] Fortunately, in the last few years, commentators have observed a renewed spirit of cooperation between States, leading to a propitious climate for positive reforms.[9]

An important aspect of the working methods of COPUOS and its Subcommittees is the consensus principle. All decisions are made with the agreement of all parties present,[10] which increases the legitimacy of the decision-making process. Of course, this also means that deliberations may take a long time to reach the necessary compromise. The consensus principle has been followed since the founding of COPUOS and there is no indication that it will be changed in the near future.

From the very beginning, the encouragement of space science was a central task for COPUOS. The mandate given to the *ad hoc* body by the General Assembly referred to the desire to continue IGY space research, as well as 'organization of the mutual exchange and dissemination of information on outer space research'.[11] This emphasis on science was continued in the resolution establishing the permanent body.[12]

Of particular relevance to space science is the STSC, and the reform of its working methods undertaken in the last five years. The STSC is the central forum for discussion of space science in the United Nations system. Until 1999, discussion of space science was confined to mere information exchange under the agenda items 'Matters relating to planetary exploration' and 'Matters relating to astronomy'.[13] This was regarded as unsatisfactory and an overhaul of STSC working methods was undertaken in 1999, on the occasion of the Third United Nations Conference on the

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[6] Kai-Uwe Schrogl, 'Basic Space Science in a Future COPUOS', above n 3, 1.
[7] Bin Cheng, *Studies in International Space Law* (1997) 184-5.
[8] Marietta Benkö and Kai-Uwe Schrogl, 'Article I of the Outer Space Treaty Reconsidered after 30 Years – "Free Use of Outer Space" vs "Space Benefits"' in Gabriel Lafferranderie (ed), *Outlook on Space Law over the Next 30 Years* (1997) 67, 69-70.
[9] Ibid 76.
[10] Cf Bin Cheng who frames the principle in the negative; according to him, consensus means that 'no decision will be taken against the strong objection of any member'; Bin Cheng, above n 7, 164.
[11] GA Resolution 1348 (XIII) (1958), (1)(b).
[12] GA Resolution 1472 (XIV) (1959).
[13] Schrogl, 'Basic Space Science in a Future COPUOS', above n 3, 1.

Exploration and Peaceful Uses of Outer Space (UNISPACE III).[14] The emphasis was shifted towards capacity building under the aegis of the UN Programme on Space Applications (PSA), which is implemented through the UN Office for Outer Space Affairs. Twelve workshops have been held within the framework of the PSA (in co-operation with ESA) on basic space science, supporting space science on a regional and international basis. A main goal is to support the growth of small research groups in universities and research establishments in the developing countries in the field of astronomy and space science, to facilitate the development of indigenous space science capabilities.[15] The workshops have also been effective in launching follow-up projects, such as the installation and upgrading of telescopes, or the commissioning of regional cooperation programmes.[16] A number of specialist scientific bodies, such as the International Astronomical Union (IAU), also enjoy observer status with the STSC, and are regularly invited to make submissions on topics of particular interest to space scientists.[17]

B. International space law treaties

The work of COPUOS has led to the development of five treaties, which were concluded between 1966 and 1979. These are generally regarded as the basis of international space law. The first, and by far the most important of these is the *Treaty on Principles Governing the Activities of States in the Exploration and Use of Outer Space, including the Moon and Other Celestial Bodies (Outer Space Treaty)*, which entered into force in 1967. It currently has 98 States Parties and has been signed but not ratified by a further 27 States.[18] Due to its widespread acceptance and recognition from the international community, particularly from the 'space-faring States', the principles embodied in the treaty are generally thought to have crystallized into customary international law.[19] The other four treaties build on aspects of the Outer Space Treaty and can be regarded as extensions to this main source of law. These other treaties have had varying international support. The *Agreement on the Rescue of Astronauts, the Return of Astronauts and the Return of Objects Launched into Outer Space* (Rescue Agreement) and the *Convention on International Liability for Damage Caused by Space Objects* (Liability Convention) have over 80 signatories. By contrast, the *Agreement Governing the Activities of States on the Moon and Other Celestial Bodies* (Moon Agreement) has just 10 States Parties. It has not been accepted by the international community and it seems highly unlikely that it will ever receive widespread ratification. According to some commentators, it is for all purposes 'dead'

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[14] See UN Doc A/AC.105/C.1/L.227 for the Working Paper on revising the agenda of STSC following UNISPACE III.
[15] UN Office for Outer Space Affairs, 'United Nations/European Space Agency Basic Space Science Workshops' (2004) <http://www.oosa.unvienna.org/SAP/bss/index.html> (at 22 November 2004).
[16] Schrogl, 'Basic Space Science in a Future COPUOS', above n 3, 3.
[17] See, eg, the background paper submitted by the IAU on the topic of obtrusive space advertising; below n 87.
[18] *Report of the United Nations Legal Subcommittee on the Work of its Forty-Third Session* (2004), UN Doc A/AC.105/826, 19.
[19] See eg Vladimír Kopal, 'Introduction to the United Nations Treaties and Principles on Outer Space' (2002), reproduced in *Proceedings of United Nations/International Institute of Air and Space Law Workshop on Capacity Building in Space Law* (2003) 10, 13.

as an international instrument.[20] For most practical purposes, it is sufficient to refer to the Outer Space Treaty, as the most widely accepted and comprehensive treaty, for an enunciation of the basic principles underlying international space law.

Before turning to the Outer Space Treaty itself, it is instructive to briefly examine its historical development. The first major step was GA Resolution 1721 (XVI) of 1961, which 'commend[ed]' to States 'for their guidance' the principle that outer space and celestial bodies 'are free for exploration and use by all States … and are not subject to national appropriation'. This aspect of the resolution was certainly groundbreaking, and much attention is deservedly devoted to it;[21] however, it is also important to recognise that this Resolution, the first to purport to broadly regulate space activities, also directed COPUOS to assist with the furthering of international scientific cooperation.[22] This was picked up in GA Resolution 1962 (XVIII) of 1963, the direct precursor to the Outer Space Treaty. Here the talk was of 'broad international co-operation' in the scientific area,[23] and that 'exploration and use of outer space shall be carried on for the benefit and in the interests of all mankind'.[24] It can be seen that the interests of space science have always been represented in the development of space law through the principle of international cooperation in outer space activities.

Again, it was a scientific achievement – the first successful 'soft' landing on the Moon by the former Soviet Union's Luna IX module, that provided the impetus for further progress.[25] As it became clear that a manned Moon landing was inevitable, the international community – in particular the two space powers at that time – became eager to further refine these principles through the conclusion of a legally binding instrument.[26] The result was the Outer Space Treaty of 1967.

Article I of the Outer Space Treaty identifies three important principles relevant to space science. Firstly, the exploration and use of outer space 'shall be carried out for the benefit and in the interests of countries, irrespective of their degree of economic or scientific development, and shall be the province of all mankind'. Secondly, outer space 'shall be free for exploration and use by all States'. Thirdly, the treaty provides for 'freedom of scientific investigation in outer space', and States are encouraged to 'facilitate and encourage international cooperation in such investigation'.

Parallels can be seen here between the Outer Space Treaty and the regime regulating the use of the deep seabed and ocean floor as set down in the United Nations Convention on the Law of the Sea. However, whereas the Convention on the Law of the Sea goes into great detail in expanding on these broad concepts and setting up mechanisms to regulate exploration and resource exploitation, the Outer Space Treaty leaves these principles at a more broad-ranging level. The development and

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[20] F G von der Dunk, 'Existing United Nations Treaties – Strengths and Needs: Commentary Paper', in UN Office for Outer Space Affairs, *Proceedings of the Workshop on Space Law in the Twenty-First Century* (Vienna, Austria, 20-23 July 1999) 19, 22.
[21] See eg the discussion in Cheng, above n 7, 151-2.
[22] Part B of the Resolution.
[23] Preamble.
[24] Article 1.
[25] Cheng, above n 7, 156.
[26] Ibid 216.

interpretation of these principles has taken a much different path, characterised by long periods of negotiation and deliberation. This perhaps reflects the somewhat theoretical nature of the topic, as large-scale exploration of outer space remains neither technologically nor economically feasible.

Other important principles laid down by the Outer Space Treaty include the principle of non-appropriation of territory in outer space (Article II), of peaceful use of outer space (Articles III-IV), of supervision and liability over space activities conducted by government and non-government bodies in a launching state (Articles VI-VII), of registration of objects launched into space (Article VIII), of non-interference with the activities of other States (Article IX) and of cooperation among the scientific community (Articles IX-XI).

The five space treaties are complemented by a number of UN General Assembly Resolutions which declare principles relating to the interpretation of these and other aspects of space law. Although the resolutions lack binding force, as they are not enshrined in treaty format, they are guidelines which inform the behaviour of States. For the purposes of this paper, it is sufficient to refer to the Principles Relevant to the Use of Nuclear Power Sources in Outer Space (resolution 47/68 of 14 December 1992), and the Declaration on International Cooperation in the Exploration and Use of Outer Space for the Benefit and in the Interest of All States, Taking into Particular Account the Needs of Developing Countries (resolution 51/122 of 13 December 1996).

III. The current situation- relevance of international space law to astronomy and basic space science

As discussed, space science played a vital role in humankind's initial forays into outer space. This is reflected in the prominence given to scientific endeavours in the Outer Space Treaty – there are two references to the importance of science in the preamble, and four in the main text. The goal was not to create an overarching space science organization, but to encourage scientific activities by States, by ensuring freedom of exploration in outer space, and encouraging international cooperation in the use of space.

A. Freedom of exploration and use

The most important principle contained in international space law relating to space science is the famous declaration, contained in Article I of the Outer Space Treaty, that exploration and use of outer space shall be free for all States. This is complemented by Article II, prohibiting national appropriation of outer space and celestial bodies 'by claim of sovereignty, by means of use or occupation, or by any other means'.

The effect of these two clauses, read together, is to establish outer space as a *terra communis*, a common area for the use of all, not subject to the exclusive sovereign jurisdiction of any single State.[27] The status of outer space is the extra-terrestrial analogue of 'freedom of the high seas' on Earth.

This is both a privilege and a burden for States. It means that every State (and private person under jurisdiction and control of a State party to the Treaty)[28] is permitted to conduct scientific exploration in outer space, without interference from other actors. It equally means that a proposed experiment to be conducted by a State in outer space should not interfere with the scientific efforts of another entity.[29]

If harmful interference is foreseen, then there is an obligation under Article IX to enter into consultations with the other party before proceeding.[30] This provision could apply in cases of interference, for example through the broadcasting on particular electromagnetic frequencies or generation of unwanted 'noise' radiation interfering with the operation of radio telescopes or other spectroscopic devices. It means that space scientists must consider the effect of their activities on others, and are encouraged to refrain from unreasonably infringing behaviour.[31] In the end, however, it should be stressed that the obligation only requires States to undertake serious consultations. In the absence of consensus, there is probably no way of legally preventing a State from undertaking a particular activity under Article IX.[32]

B. Freedom of scientific investigation, International cooperation and the 'Benefits principle'

Article I of the Outer Space Treaty states that 'there shall be freedom of scientific investigation in outer space … and States shall facilitate and encourage international cooperation in such investigation'. Although the 'freedom of scientific investigation' is phrased in mandatory form, State practice has been to regard this as a

[27] Lynn M Fountain, 'Note: Creating Momentum in Space – Ending the Paralysis Produced by the "Common Heritage of Mankind" Doctrine' (2003) 35 *Connecticut Law Review* 1753, 1757.
[28] Article VI requires States to authorize and supervise activities undertaken by 'non-governmental entities' in outer space, to ensure they are carried out in accordance with Treaty provisions.
[29] See also Hulsroj, who argues that the current practice does not reflect the principle of 'free use' since the first user is accorded priority and is protected against interference from others. As he puts it, 'there is no longer value neutrality because speed becomes the prioritised asset'; Peter Hulsroj, 'Beyond Global: The International Imperative of Space' (2002) 18 *Space Policy* 107, 109. In this author's opinion, such a situation is unavoidable, since to allow complete 'free use', regardless of possible interference to others, would lead to a situation where nobody is able to effectively utilize the resource, which is in no-one's interest. Implicitly, a value-judgment must be made, either in favour of utility or complete freedom. The current practice reflects a preference for the former.
[30] Bin Cheng emphasizes that the obligation to consult is dependent on the somewhat subjective premise that the State has 'reason to believe' that the proposed conduct would cause 'potentially harmful interference'; Cheng, above n 7, 258.
[31] One of the most infamous interference-causing scientific experiments was conducted by the United States in 1963 (before the Outer Space Treaty) under the name 'Project West Ford'. It involved the release of hundreds of millions of small dipoles (needles) into orbit around the Earth to act as a passive reflector for radio waves. The experiment was conducted despite the protests of astronomers, who feared the adverse impact on scientific activities and observations. Although the needles were designed to disperse naturally into the Earth's atmosphere after five to ten years, there is still controversy as to whether West Ford continues to contribute to the 'space debris' problem. See generally Cheng, above n 7, 256-8.
[32] Cheng, above n 7, 403; this point was also discussed at the UN/Republic of Korea Workshop on Space Law, 'United Nations Treaties on Outer Space: Actions at the National Level' (Daejoen, Republic of Korea, 3-6 November 2003), during the presentation of FG von der Dunk (5 November 2003).

statement of principle, referable to the more general principle of freedom of use and exploration, rather than a source of specific duties or obligations relating to scientific activities.[33]

The second part of Article I expresses the principle of international cooperation in scientific research. Here, reference should be made back to the first part of Article I, which states that activities in outer space shall be carried out for the benefit of all countries, and are the province of humankind. Read in conjunction with the preambular provisions, the goal of this principle is the 'development of mutual understanding' and the 'strengthening of friendly relations between States and peoples'. This is further referable back to Art 1 (3) of the UN Charter, which declares the encouragement of 'international co-operation in solving international problems of an economic, social, cultural, or humanitarian character' as a fundamental purpose of the United Nations. The emphasis on international cooperation is a leitmotif in the Treaty, and apt given the reality of modern science, where experts often think of themselves firstly as 'scientists' and only secondly as 'nationals' of a particular country. Basic space science, as opposed to applied space science, has traditionally been considered a field in which open, cooperative work should be encouraged.[34]

The Outer Space Treaty does not go into any detail in explaining what is meant by the broad statement that the 'exploration and use of outer space' be undertaken for the benefit of all countries. State practice makes it clear, however, that Article I does not impose specific obligations on States to directly share the benefits of use. Rather, the activity should contribute to the good of the international community in a broad sense,[35] which incidentally is such a broad concept itself, that it allows States to interpret it as they see fit.

In regard to principles governing international cooperation in the use of outer space, the General Assembly addressed the issue in 1996 through the adoption of a *Declaration on International Cooperation in the Exploration and Use of Outer Space for the Benefit and in the Interest of All States, Taking Into Particular Account the Needs of Developing Countries*. As the name suggests, particular emphasis is given to the interests of developing countries, who themselves lack the capability for large-scale exploration or use of outer space, but who are eager to share in any benefits that may arise from such research. The Declaration leaves States free to negotiate their own agreements for the promotion of international cooperation, but urges that those agreements be 'fair and reasonable' and concluded on an 'equitable and mutually acceptable basis'. The advanced space-faring nations are encouraged to enter into cooperative agreements with developing countries and countries with incipient space capabilities to foster the development of space programmes in these States. Cooperation is encouraged not only between States, but also on commercial, regional and non-governmental levels. Importantly, the Declaration recognizes the right of parties to protect their 'legitimate rights and interests' under such agreements, for example intellectual property rights and the principle of rational allocation of resources.

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[33] Cheng, above n 7, 252-3.
[34] Commission on Physical Sciences, Mathematics, and Applications and Space Science Board, *US-Europe Collaboration in Space Science* (1998) 15.
[35] Tim Smith, 'A Phantom Menace? Patents and the Communal Status of Space' [2003] *Victoria University Wellington Law Review* 33, 43.

Article XI of the Outer Space Treaty should also be mentioned in this context. It directs States undertaking activities in outer space to 'inform the Secretary-General of the United Nations as well as the public and the international scientific community, *to the greatest extent feasible and practicable*, of the nature, conduct, locations and results of such activities'.[36] This had a dual purpose; firstly, to ensure observance of the demilitarization provisions of the Treaty,[37] and secondly, to complement the principle of international cooperation as articulated in Art I.[38] However, State practice in interpreting the italicised portion above has not resulted in the free dissemination of information. The section is seen as purely discretionary, and almost redundant.[39]

Despite this, international cooperation does of course take place. With the increasing sophistication of space science, scientists require more sensitive, and hence more expensive equipment. Space agencies have not been immune to cutbacks in government spending, which also places pressures on budgets for scientific missions. International cooperation becomes in this context not only laudable from a diplomatic perspective, but also necessary from a financial, cost-sharing viewpoint.[40]

Here, two examples will be discussed; the International Space Station project, and the World Space Observatory proposal.

International Space Station

The International Space Station (ISS) is the largest scientific cooperative programme in history, drawing on the resources and scientific expertise of 16 countries.[41] The first launch took place in 1998, and completion is not expected in the near future. The station will contain six laboratories, and provide more room for research than any spacecraft in history.[42] The total construction and operational costs of the Station are expected to total 100 billion Euros.[43]

The legal foundation of ISS is provided by the Intergovernmental Agreement (IGA), signed by representatives of all participating States. The IGA establishes

> a long term international co-operative framework among the Partners, on the basis of genuine partnership, for the detailed design, development, operation, and utilization of a permanently inhabited civil international Space Station for peaceful purposes, in accordance with international law.[44]

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[36] Emphasis added.
[37] Cheng, above n 7, 253
[38] Ibid.
[39] Ibid 403-5. Cheng calls the provision 'absolutely supine', a 'pseudo-obligation', and 'even an embarrassment'.
[40] CPMSA and SSB, above n 34, 39.
[41] National Aeronautics and Space Administration, 'International Partners and Participants' (2004) <http://spaceflight.nasa.gov/station/reference/partners/index.html> (at 22 November 2004).
[42] National Aeronautics and Space Administration, 'Space Station Assembly' (2004) <http://spaceflight.nasa.gov/station/assembly/index.html> (at 22 November 2004).
[43] European Space Agency, 'International Space Station: How Much Does It Cost?' (2004) <http://www.esa.int/export/esaHS/ESAQHA0VMOC_iss_0.html> (at 22 November 2004).
[44] Art 1(1).

With such a complex and expensive co-operative arrangement, obtaining certainty in the allocation of property rights is essential.

The basic rule of the IGA is that each Partner retains ownership over the elements that they provide.[45] For this purpose, the European States Parties are treated as one homogenous entity ('the European Partner'), who entrust all property rights in their equipment to ESA.[46] Each Partner retains 'jurisdiction and control' over the elements it provides, subject to other relevant provisions in the IGA, Memoranda of Understanding and other implementing arrangements.[47] The applicable national law in each Station component thus corresponds to that of the providing Partner.[48] Additionally, Partners retain use of those elements which they provide,[49] subject to allocations made to compensate for the provision of operational resources from other Partners.[50] For example, ESA retains only 51% of the 'user accommodations' on its laboratory module, and allocates the remaining 49% between USA and Canada, in recognition of the other essential infrastructure and resources provided by these Partners on ISS.[51] Partners may barter or sell their utilization allocations between themselves, or to non-Partners with the consensus of the other Partners.[52]

Of particular importance is the area of Intellectual Property Rights (IPRs). The IGA provides that for the purposes of IP law, activities will be deemed to have occurred in the territorial jurisdiction of the Partner in whose flight element the activity took place.[53] For example, an invention occurring in the Japanese space laboratory will be deemed to have occurred in Japan. This does not in itself affect ownership of the invention – it only assists in the application of terrestrial IP law where the location of inventorship is often important. The inventor is still free to apply for a patent in a State of his/her choice.[54] The IGA also restricts the operation of Partner States' respective invention secrecy laws, which limit the filing or dissemination of patent applications for national security purposes.[55] These restrictions may not be invoked to prevent a non-national filing for a patent in a Partner State other than the State with territorial jurisdiction, as long as that Partner State has a patent protection regime.[56] For example, a French national who develops an invention in the US module cannot be prevented by the US from filing a patent

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[45] Art 6(1).
[46] Art 6(2).
[47] Art 5(2).
[48] European Space Agency, 'International Space Station: Legal Framework' (2004) 4 <http://www.esa.int/export/esaHS/ESAH7O0VMOC_iss_0.html> (at 22 November 2004).
[49] Art 9(1).
[50] Art 9(1). See also, eg, Memorandum of Understanding between NASA and ESA, Art 8(3)(b).
[51] NASA-ESA MOU, Art 8(3)(b).
[52] IGA Art 9(3).
[53] Art 21(2). Note that 'intellectual property' is defined to have the meaning of Article 2 of the Convention Establishing the World Intellectual Property Organization, done at Stockholm on 14 July 1967; Art 21(1). This is a 'broad definition, which includes, *inter alia*, inventions, works of authorship, and trade secrets'; NASA Office of the General Counsel, 'Intellectual Property and the International Space Station: Creation, Use, Transfer, Ownership and Protection' (1999) 5 <http://www.hq.nasa.gov/ogc/iss/main.html> (at 22 November 2004).
[54] ESA, 'International Space Station: Legal Framework', above n 48, 4.
[55] NASA OGC, above n 53, 6.
[56] IGA Art 21(3).

application in France on national security grounds, since France has an invention secrecy system.[57]

Legal rules relating to IPRs of private entities, for example academic and industrial users, are determined by the contractual framework agreed to between these parties and the Partner State.[58] The terms of such contracts can vary greatly, which in turn affects the ownership status and exploitation rights of the intellectual property.[59] However, such contracts generally include an obligation in favour of the Partner State, for example to grant an irrevocable, nonexclusive, non-transferable, royalty-free license over the invention,[60] or to grant access to the data or invention for research, demonstration, test and evaluation purposes.[61]

Scientific data obtained on the ISS by space agencies will be distributed in accordance with their respective data publication policies. NASA, for example, has a policy of ensuring the 'widest practical and appropriate dissemination' of data.[62] To this end, it releases all data within six months of acquisition and validation, other than in exceptional circumstances.[63] Principal Investigators are additionally obliged to publish their findings in peer-reviewed literature.[64]

World Space Observatory

Another example of the principle of international cooperation being put into academic practice is the current proposal for the construction of a World Space Observatory (WSO). The programme involves a substantial number of countries working together, with the support of the United Nations,[65] in a joint effort to launch a satellite to probe the ultraviolet spectrum. This differs from previous joint missions such as the Hubble Space Telescope,[66] involving two or three partners, all of which were already advanced space-faring nations. The WSO foresees cooperation between space-faring countries and developing nations across all areas of the mission.[67]

While the mission control centres would be centralized as much as possible in those nations mainly responsible for the spacecraft's operations, scientific centres

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57 NASA OGC, above n 55, 6.
58 ESA, 'International Space Station: Legal Framework', above n 48, 4.
59 Ibid.
60 NASA OGC, above n 55, 16.
61 Ibid 17.
62 NASA Procedural Requirements, 'Requirements for Documentation, Approval, and Dissemination of NASA Scientific and Technical Information (STI)' (Revalidated 12 August 2004), NASA Directive NPR 2200.2A, [1.6].
63 NASA, 'Space Science Data Archives' (2004) <http://science.hq.nasa.gov/research/space_science_data.html> (at 22 November 2004).
64 Ibid.
65 *Report on the Third United Nations Conference on the Exploration and Peaceful Uses of Outer Space* (Vienna, 19-30 July 1999), UN Doc No A/CONF.184/6, [207] ('*UNISPACE III Report*').
66 International Space University, 'Technology Research Advancing Cooperative Knowledge Sharing: TRACKS to Space' (2003) 3 <http://wso.vilspa.esa.es/docs/WCC/DOC/Attachments/PRG-PUB-0001-1-0.PDF> (at 22 November 2004).
67 Ibid.

would be established in every country willing to host one.[68] Those centres would be responsible for conducting on-board experiments, and thus a great deal of integration and coordination would be required to avoid duplication and redundancies.[69] The decentralized scientific structure should allow developing countries direct access to a world-class observation facility, which would allow scientists from those countries to participate in cutting-edge astrophysics in their own cultural environment.[70] Importantly, all data gathered would remain in the public domain, reflecting the principle of freedom of scientific endeavour contained in Articles I and XI of the Outer Space Treaty.

The project is perhaps modest in scope, but would serve an important scientific purpose and could set a precedent for future international collaboration in space science.

C. Intellectual Property Rights in Outer Space

Intellectual property rights (IPRs) refer to a legal construct of property rights designed to protect ownership over intangible 'intellectual' creations.[71] The most typical incident of IPRs is the patent. The patent provides a legal mechanism for the patent holder to prevent others from exploiting the invention described therein.[72] These rights are created unilaterally by States, and are thus only directly enforceable in territory under the jurisdiction of the granting State.[73]

The enforcement of IPRs in outer space is theoretically problematic, since Article II of the Outer Space Treaty expressly establishes that 'outer space, including the Moon and other celestial bodies, is not subject to national appropriation by claims of sovereignty, by means of use or occupation, or by any other means'. On a more abstract level, the negative nature of patents may seem conceptually incompatible with the 'freedom of exploration and use' provision of Article I. However, State practice makes it clear that existing national patent regimes may be legitimately extended into outer space.[74] The principle of free exploration of space yields to the prioritized imperative of observing patents, presumably in the interest of encouraging commercial investment.[75] This means that outer space actors must respect the terrestrial IP law of the State in whose name their spacecraft is registered.

The legal basis for exercising jurisdiction is drawn from Article VIII of the Outer Space Treaty, which provides that States retain 'jurisdiction and control' over

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[68] *Report On The 8th United Nations/European Space Agency Workshop On Basic Space Science: Scientific Exploration From Space* (Mafraq, Jordan, 13-17 March 1999), UN Doc No A/AC.105/723, [33].
[69] Ibid.
[70] Ibid [34].
[71] Smith, above n 35, 36.
[72] Ibid.
[73] Ibid 36-7. 'Jurisdiction' in this sense refers to both prescriptive and enforcement jurisdiction.
[74] Smith, above n 11, 42.
[75] See eg Marguerite B Broadwell, 'Intellectual Property and the Economic Development of the International Space Station' (2000), presented at the Space Technology and Applications International Forum (Albuquerque, USA, February 2000), 2 <http://commercial.hq.nasa.gov/files/staifpapers/intellectual_property.pdf> (at 22 November 2004).

space objects launched under their registry.[76] In general, the applicable patent law is the law of the 'launching State'. This can cause problems in joint ventures, where several States are responsible for the launching of a spacecraft. In such cases, the IGA or MOU will usually set down rules relating to intellectual property. For example, as discussed earlier, the IGA for the ISS divides jurisdiction among the different modules (for the purposes of IP law) according to which Partner State contributed to the provision of the part.

More generally, where space research is carried out internationally, IPR allocation may be determined by any bi- or multi-lateral agreements that have been concluded between the States involved concerning intellectual property.[77] With the increasing commercialization of space exploration, States will try to attract private operators through a strengthening of IPRs. As with all branches of science, as more practical applications are found, IPRs will play an increasingly important role.

D. Peaceful uses of outer space

A primary goal behind the establishment of COPUOS was the desire to avoid the militarization of outer space. To this end, Article III of the Outer Space Treaty directs that all exploration and use of space is to be undertaken 'in accordance with international law' and 'in the interest of maintaining international peace and security'. Article IV forbids States from placing nuclear weapons or other weapons of mass destruction in Earth orbit, on other celestial bodies, or otherwise in outer space. Furthermore, the Moon and other celestial bodies are to be used 'exclusively for peaceful purposes'.

It may be observed that the Outer Space Treaty effects an incomplete, two-tiered demilitarization of space. While the Moon and other celestial bodies are completely demilitarized, only the positioning of weapons of mass destruction in outer space is forbidden, and it is specifically foreseen that military personnel may be involved in research and exploration activities.

The 'peaceful purposes' provisions are central to the Outer Space Treaty regime, but of only marginal significance to space science. They are only relevant to the extent that they affect experiments with possible military significance. For example, as Winkler points out, although it could be interesting from a scientific viewpoint to observe the consequences of an orbital nuclear detonation on the magnetic field of a planet, such an experiment would clearly violate the spirit and wording of the Outer Space Treaty.[78] Less obvious examples may be imagined, particularly in cases where scientific research also has possible military applications. For example, orbiting space telescopes with space-to-ground reconnaissance capabilities could be seen as contrary to the 'interest of maintaining international

[76] Rules pertaining to registration are set down in the Registration Convention of 1976.
[77] See eg The Agreement Between the United States of America and the Russian Federation Concerning Cooperation in the Exploration and Use of Outer Space for Peaceful Purposes (Signed in Washington DC, 17 June 1992) <http://www.jaxa.jp/jda/library/space-law/chapter_4/4-2-2-6_e.html> (at 22 November 2004).
[78] Note that this would also contravene the provisions of the Convention on the Prohibition of Military or Any Other Hostile Use of Environmental Modification Techniques (1978), Art 1(1).

peace and security'. State practice makes it clear, however, that the operation of military reconnaissance satellites is not considered inconsistent with the OST.[79]

E. Registration/Liability provisions

As part of the regime set up under the Outer Space Treaty, States are required to register all objects launched into space with the United Nations.[80] The details of this requirement were set down in the *Convention on Registration of Objects Launched into Outer Space* (Registration Convention) from 1975. States are obliged to supply basic information about the object, including launch location, basic orbital parameters (e.g. nodal period, inclination, perigee/apogee), and the general function of the object, for insertion into a central, openly-accessible Register.[81]

The establishment of the Register is intended to assist in questions of liability, where damage is caused by a space object. The principles and procedures governing the assignment of liability are set down in the Liability Convention, which expands on Articles VI and VII of the Outer Space Treaty. The Convention introduces the concept of a 'launching State', and imposes strict liability on the 'launching State' for any damage caused on the Earth's surface by its space objects. It is important to read the Liability Convention in conjunction with Article VI of the Outer Space Treaty. In contrast to normal standards of international responsibility, in matters of space law, a State is additionally responsible for its 'national activities in outer space'. Thus States must act to carefully regulate the activities of commercial and private enterprises that are involved in space insertion, since the States are internationally liable for damage caused by their activities. In particular, private individuals considering space launches must obtain adequate insurance coverage to cover any potential claims for damage caused.

Unfortunately, there is no universally accepted interpretation of 'national activities'. Some countries have defined this as covering all activities conducted from their territory, as well as activities of their nationals in other jurisdictions.[82] This is the broadest possible interpretation. Other countries have adopted a narrower interpretation, applying only to activities of their nationals.[83] This unsatisfactory situation is sure to cause problems in the future, with the increasing prevalence of international cooperation in space activities. For example, a probe may be built by an international space science body registered in State A, launched on a space vehicle belonging to State B from the sovereign territory of State C. Ascertaining the applicable jurisdiction for the purposes of liability, registration, criminal and IPR

[79] Cheng, above n 4, 585-6.
[80] Art VIII foresees that States will register space objects launched into outer space for the purposes of retaining 'jurisdiction and control'. See also GA Res 1721 (XVI), Part B, which called upon States to immediately register objects launched into space with COPUOS.
[81] The Register is hosted on the website of the UN Office for Outer Space Affairs <http://www.oosa.unvienna.org/SORegister/regist.html>.
[82] The *Space Activities Act 1998* (Australia), s 3, indicates that the Act regulates space activities conducted in Australia and by Australian nationals outside Australia. United States and Swedish legislation are similarly wide-ranging; 49 USC §70104(a), Swedish Space Activities Act of 1982 (1982:962), supplemented by the Decree on Space Activities (1982:1069). See generally Cheng, above n 7, 487.
[83] For example, the *Outer Space Act 1986* (UK), s 2.

jurisdiction becomes highly problematic. The launching of any space object is thus an activity for which legal advice should be sought.

F. Nuclear Power Sources

In 1978, in a well-publicised incident, a Soviet Cosmos 954 satellite carrying a nuclear power reactor crashed into Canadian territory and scattered debris over a large area. While the recovery and compensation phases were more or less conducted in accordance with international law, this crash was the catalyst for the development of guidelines specifically regarding the use of nuclear power sources (NPS) in outer space.

In 1992, the General Assembly adopted the *Principles Relevant to the Use of Nuclear Power Sources in Outer Space*.[84] While acknowledging that NPS have an important role to play in space exploration, the Principles try to establish a safety regime for reducing the risk of accidental exposure of the public to radiation or radioactive material. To this end, NPS may only be used for missions 'which cannot be operated by non-nuclear energy sources in a reasonable way'.[85] Use of nuclear power is prohibited in low-Earth orbit unless the spacecraft is relocated to a 'sufficiently high orbit' after the operational part of its mission. A 'sufficiently high orbit' is defined as an orbit where the fission products of the nuclear reaction have time to decay to actinide-level activity. Only uranium-235 reactors are permitted to be used. Radioisotopic generators may be used with other fuels, so long as the containment systems are capable of surviving the heat and aerodynamical forces of an unforeseen re-entry.

From a legal perspective, the Principles represent an internationally-agreed interpretation of space law provisions relating to NPS. They confirm that States incur international responsibility for any national activities causing damage through the use of NPS. They impose an obligation on States using NPS to inform other States of any foreseen malfunctions and to assist in containing any terrestrial contamination that may be caused. In accordance with the Liability Convention, States are absolutely liable to compensate any damage caused by their space objects, including damage due to the radioactive source.

Due to the possibility of catastrophic damage,[86] States must be very careful in launching, or licensing the launch of, satellites containing NPS. This means that space scientists must also look wherever possible to other means of powering scientific probes.

IV. Future legal challenges for astronomy and basic space science - preservation of the space environment

When the basic principles of space law were drafted in the 1960s, outer space was more or less regarded as inexhaustible. In one sense, this is true. A single metallic

[84] GA Res 47/68 (14 December 1992).
[85] Principle 3.
[86] Some estimates put the possible human death toll in the hundreds of thousands- see Regina Hagen and Jürgen Scheffran, 'Nuclear Space – an Indispensable Option?' (2001) 17 *Space Policy* 263.

asteroid one mile in diameter, of which several are known to pass close to Earth, contains 30 times more metal than humans have mined through history and could have a market value of US$20 trillion.[87] However, the experience of the last forty years of space exploration have shown us that certain aspects of outer space are indeed limited resources, and that the protection of the space environment must become a priority in future space regulation.

In this section, two of the main space environmental problems in the context of space science will be discussed. Here we are concerned with the role space law can play in preserving the space environment.

A. Radio/Light Interference

A major problem for ground-based astronomers is the increasing level of interference occurring from space-related activities. Given that telescopes and detectors are now investigating objects 100 million times fainter than those visible with the naked eye,[88] and radio telescopes are studying similarly weak transmissions, it is obvious that the increased amount of space traffic, and above all the radiation transmitted from this traffic, could have a devastating impact on astronomy. Persistent lobbying from expert groups such as the IAU has succeeded in bringing this problem to the attention of the international community.[89] Most notably, the UNISPACE III conference declared that 'attention should be given to preserving or restoring astronomical observation conditions to a state as close to natural as possible by any practicable means'.[90]

In terms of light pollution, a major (space-based) threat to astronomy comes from projects to insert 'space advertising' material into orbit. For example, the IAU documents a 1996 proposal from a US-based firm to unfurl a 1 km² 'Space Billboard' that would have rivalled the full Moon in size and brightness.[91] Had the project come to fruition, it would have effectively destroyed any possibility for observation in that broad area of the night sky.

Proposals for Reform

There is a lack of clear regulation in the area of 'space advertising' which may be endangering the future of ground-based astronomy. The IAU has proposed a ban on 'obtrusive space advertising', identifying two main characteristics of such objects. A project may be deemed as 'advertising' if it is without 'factual scientific or technical function', and/or where the revenues gained flow only to the originators. This would avoid genuine scientific missions from being prohibited, although they are

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[87] Sol Company, <http://members.nova.org/~sol/station/ast-mine.htm> (at 22 November 2004).
[88] International Astronomical Union, 'Obtrusive Space Advertising and Astronomical Research' (2001), Background Paper for the UN Committee on the Peaceful Uses of Outer Space, UN Doc No A/AC.105/777, [5].
[89] J Andersen, 'History, Strategy and Status of IAU Actions' in R J Cohen and W T Sullivan (eds), *Preserving the Astronomical Sky* (2001), IAU Symposium 196 (Vienna, Austria, 12-16 July 1999) 10, 16-21.
[90] UNISPACE III Report, above n 65, 29-30.
[91] IAU, above n 88, [16].

obtrusive in the astronomical sense (for example ISS). In determining the extent of obtrusiveness, the IAU names brightness, visibility period and extent of illumination as three critical criteria. It is interesting to note that the US has already prohibited the issuing of launch licenses for 'obtrusive space advertising', which it defines as 'advertising in outer space that is capable of being recognized by a human being on the surface of the Earth without the aid of a telescope or other technological device'.[92]

The IAU's proposal was considered by COPUOS and its Scientific and Technical Subcommittee in 2002. The Subcommittee agreed that space advertising poses a 'grave concern for the future',[93] and 'noted with appreciation' the preventative legislative efforts of the US. However, despite this and the recommendation from UNISPACE III, COPUOS fell short of endorsing legal change and the item 'space advertising' was removed from the agenda thereafter. Hence there is no comprehensive international prohibition on space advertising of the sort discussed. It remains a matter to be determined by individual countries.

The huge increase in telecommunications satellites is also threatening the future of radio astronomy. These satellite transponders broadcast signals millions of times stronger than the faint cosmic whispers received by radio telescopes. To put into context the difference in magnitude, the IAU points out that if a single mobile phone were placed on the moon, it would be among the four brightest sources in the radio sky.[94] The strength of the transmissions currently being sent by communications satellites is such that 'spillover' into adjacent frequency bands is inevitable and growing enormously.[95]

The current regulatory framework governing electromagnetic transmission in the radio range is largely set down by the International Telecommunication Union (ITU) in its Radio Regulations.[96] The ITU coordinates the use of the radio spectrum, dividing bandwidth and frequencies between countries for various communications uses.[97] In the past, radio astronomers were granted exclusive or priority usage over certain frequency bands of particular scientific interest. Furthermore, scientists were formerly able to place their observatories in largely uninhabited, 'radio-quiet' areas where the prospect of interference was not so great. However, with the global coverage of telecommunication satellites, problems of 'spillover' and non-compliance, the fragile status-quo situation no longer seems sustainable.

Among the solutions that have been put forward, the most interesting from a legal standpoint is the introduction of a system of 'radio quiet zones' (RQZs). The RQZs would be designated areas of the Earth where satellite communications signals would be kept to tolerable levels, compatible with radio astronomy observations.[98] Such an approach would require a large amount of international cooperation and

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[92] 49 USC §70102(8) (2002).
[93] *Report of the United Nations Scientific & Technical Subcommittee on the Work of its Thirty-Ninth Session* (2002), UN Doc A/AC.105/786, [140].
[94] IAU, above n 88, [8].
[95] F G von der Dunk, 'Space for Celestial Symphonies? Towards the Establishment of International Radio Quiet Zones' (2001) 17 *Space Policy* 265, 265.
[96] The Radio Regulations are *lex specialis* and *lex posterior* and hence take precedence over the OST, in particular Art 1(3) guaranteeing freedom of scientific exploration.
[97] Hulsroj, above n 29, 107.
[98] Von der Dunk, 'Space for Celestial Symphonies?', above n 94, 266.

regulation, quite possibly involving the drafting of a new treaty or protocol. It has been pointed out that the ITU at present would lack the jurisdiction to implement such a proposal.[99] The regulatory alternative would be to strengthen the current system and possibly introduce a frequency-sharing scheme with other services (since radio astronomers do not require temporal exclusivity) .

Further investigation into the establishment of RQZs was encouraged by the 1999 Technical Forum 'Preserving the Astronomical Sky', conducted in the run-up to UNISPACE III. The Workshop on Space Law in the Twenty-First Century recommended that legal action be taken to reserve radio bands for astronomy and to protect it from the problem of 'spill-over'. Finally, UNISPACE III itself adopted, as part of "The Space Millennium: Vienna Declaration on Space and Human Development", a recommendation that

> [A]ll users of space [should] consider the possible consequences of their activities, whether ongoing or planned, before further irreversible actions are taken affecting future utilization of near-Earth space or outer space, especially in areas such as astronomy…[100]

To date, this statement has not led to substantive legal change; however, it is clearly a topic that requires action, and the UNISPACE III declaration, as an expression of policy accepted by all participating States, provides an impetus for future progress.

B. Space Debris

Also of global concern to astronomers and space scientists is the growth in what is commonly known as 'space debris', that is, objects in Earth orbit that do not serve a functional purpose. According to some estimates, 95% of all man-made objects currently in outer space can be classified as 'space debris'.[101] These objects range from sub-millimetres to metres in diameter, are difficult to detect and can have impact velocity on collision of up to 15 km/s.[102] At such speeds, studies show that an impacting particle of 1g mass compares by approximation with the explosion energy of 10g of dynamite.[103]

Space debris causes problems for three reasons. Firstly, the proliferation of objects in the sky can adversely affect ground-based astronomical observations, which depend on extremely high sensitivity and resolution. If an object passes through the field of view of a space telescope during exposure, this can degrade both photographic and photometric studies,[104] and intensely bright space debris objects can even cause physical damage to sensitive equipment.[105] Secondly, space debris threatens space-

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[99] Ibid 272.
[100] UNISPACE III Report, above n 65, 3.
[101] Maureen Williams, 'Maintaining the Space Environment: Commentary Paper' in UN Office for Outer Space Affairs, *Proceedings of the Workshop on Space Law in the Twenty-First Century* (2000) 212, 213.
[102] Dietrich Rex, 'Will Space Run Out of Space? The Orbital Debris Problem and its Mitigation' (1998) 14 *Space Policy* 95, 100 (Fig 1).
[103] Ibid 100.
[104] UNISPACE III Report, above n 65, 29.
[105] Lubos Perek, 'Maintaining the Space Environment: Discussion Paper' in UN Office for Outer Space Affairs, *Proceedings of the Workshop on Space Law in the Twenty-First Century* (2000) 197, 203.

based observatories, since the consequences of the impact of even a small particle of space debris could be catastrophic for such satellites. Indeed, in 1996, the French CERISE spacecraft was struck and partially disabled by the impact of a fragment of an exploded Ariane upper stage.[106] Thirdly, since there are a finite amount of useful orbital 'slots', non-functional satellites that remain in orbit are in effect congesting this limited natural resource.

Most commentators agree that the issue of space debris requires immediate action. According to one simulation, if space operators simply continue to operate as they do currently, the growth in debris will be such that spaceflight in near-Earth orbit will be paralyzed within 100 years.[107] The risk of collision and destruction of satellites launched would simply be too large. Indeed, even a complete and immediate cessation of space activities would not reduce the amount of debris currently in orbit, due to the collisions that will statistically take place between objects already present, which in turn produce more debris (a self-sustaining chain reaction). Moreover, this overcrowding is permanent. It is physically impossible to design a 'vacuum cleaner' to clean up the low-Earth orbit.[108] Therefore, it is imperative to take measures now to halt the build-up of debris.

Currently, there is no comprehensive legal framework dealing with the issue of space debris. Articles VI-IX of the Outer Space Treaty, along with the Liability and Registration Conventions do establish a regime of consultation, registration, international responsibility and liability for damage caused by objects (which includes component parts of such objects) launched into space. However, the imposition-of-liability approach to encouraging prudent behaviour does not function as effectively in zero-gravity as on Earth.

Firstly, it is almost impossible to track the origin of small pieces of debris, which may be second- or third-generation fragments from a series of explosions. In the case of collision, the chances of being able to identify the State responsible for the emission of debris are remote.

Secondly, even assuming the damage-causing debris can be traced, several commentators have pointed out that it is unclear how space debris damage would be treated under the Outer Space Treaty and Liability Convention. In the case of damage caused by the 'space object' of one State to persons or property of another State other than on the Earth's surface, under the Liability Convention there is a requirement to prove 'fault' on the part of the launching State.[109] This would seem to involve more than the mere production of debris as a result of legitimate space operations, as this would be tantamount to the imposition of strict (absolute) liability as for damage occurring on Earth.[110] This suggests that a claimant State would have to establish

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[106] *Report of the United Nations Scientific & Technical Subcommittee on the Work of its Thirty-Fifth Session* (1998), UN Doc A/AC.105/697, 19.
[107] Rex, above n 100, 101.
[108] Ibid. This is not to mention the legal issues that would be involved in destroying or removing space debris owned by another State; see United States National Scientific and Technical Council, *Interagency Report on Orbital Debris* (1995), 47.
[109] Liability Convention Art 3.
[110] United States National Scientific and Technical Council, above n 107, 46.

some sort of negligence on part of the debris-producing State, which would lead to debate over difficult issues of foreseeability and reasonableness.[111]

Although it is in the interests of all space-faring nations to limit the amount of space debris, the current regime with its imposition of fault-based liability alone seems insufficient as an incentive for States to take decisive action.

Proposals for Reform

Various international technical and legal bodies have been investigating the issue of space debris over the last 10-15 years.

From the technical perspective, the item 'space debris' first appeared on the agenda of the STSC of COPUOS in 1994, and has been the subject of two consecutive four-year working plans. To date, the outcome of this deliberation has been the production of a Technical Report (in 1999), which provided an understanding of the debris environment, assessed risks and analyzed debris mitigation measures being undertaken by various operators.[112] Then, in 2003 the Inter-Agency Space Debris Coordination Committee (IADC), an international forum of national and regional space agencies, developed a set of Mitigation Guidelines to reduce space debris emissions. The Guidelines are not legally binding, being instead strictly recommendatory in nature. They were discussed by the Subcommittee in 2004, and it was suggested that they be further amended by the IADC in the light of comments received by member States for presentation to the Subcommittee during its next session in 2005.

These mitigation measures include two main aspects. Firstly, orbital explosions of satellites (both during and post-mission) should be avoided through venting of residual fuel, discharging of batteries and depletion of flywheels and momentum wheels. Secondly, satellites in near-Earth orbit should be de-orbited after their functional lifetimes, preferably crashed directly into an ocean or at least manoeuvred into an orbit from which natural atmospheric drag will bring the object out of orbit. Of course, care must be taken during such an operation to avoid debris reaching the Earth's surface, unduly risking people or property.

According to estimates, the cost of mitigation measures may add 15-20% to the cost of launching a space object. Given the growing commercialization and competition in space activities, the reality is that no operator is going to voluntarily assume such costs unless they are made mandatory for all competitors.[113] Hence the need to find an international solution to this issue.

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[111] Ibid.

[112] *Report of the United Nations Scientific & Technical Subcommittee on the Work of its Thirty-Ninth Session* (2002), UN Doc A/AC.105/786, [121].

[113] Rex, above n 101, 105. Although it must be pointed out that some countries have voluntarily undertaken debris mitigation measures– for example NASA's 2003 'Policy for Limiting Orbital Debris Generation'. France and India have also recently de- or re-orbited satellites for this purpose; *Report of the United Nations Scientific & Technical Subcommittee on the Work of its Forty-First Session* (2004), UN Doc A/AC.105/823, 20.

On the legal side, the International Law Association (ILA) adopted in 1994 a Draft Instrument for the Protection of Damage Caused by Space Debris. The Draft Instrument contains a definition of 'space debris', and explicitly makes States internationally *and strictly* liable for damage caused by 'space debris' originating from objects launched by them into space. A duty is imposed on States to cooperate in the implementation of the Draft Instrument and the reduction and control of 'space debris'. There is an obligation to negotiate 'in good faith' with other States to whom the proposed or foreseen production of space debris is of concern. A dispute resolution mechanism is also integrated into the Draft Instrument. The main departure from the provisions of the Liability Convention is the imposition of strict liability on States for all damage caused by their space debris, which is intended to act as a strong incentive to minimize debris production.

However, there has been little progress made in implementing the Draft Instrument into a binding international agreement. At least since 1995, attempts have been made by some States to have the issue included in the agenda of the LSC of COPUOS. These attempts have consistently failed to win a consensus. There seems to be a reluctance to discuss the matter in the LSC while the STSC is still involved with the subject. With the STSC scheduled to finish its consideration next year under the working plan, it will be interesting to see how the LSC approaches the matter in the near future. It will have at its disposal detailed legal and technical proposals and hence the ability to construct a regime for the regulation of the space debris problem.

While the drafting of a comprehensive international Convention to regulate space debris would be ideal, incorporating legal provisions (definitions, international responsibility, liability, registration, etc) as well as technical rules (binding mitigation measures), the problem is so acute that a faster solution may be required. Given the consensus-based approach of COPUOS, and the difficulty involved in finding an acceptable compromise between the scientific and economic imperatives, the drafting of a new Convention could take up to ten years, with no guarantee of success. Lafferranderie suggests a more pragmatic two-part approach, with the adoption of a set of Principles on the broader issues (international responsibility, cooperation, liability etc), to 'complement the existing legal provisions', accompanied by the publication of a technical 'code of conduct' along the lines of the Mitigation Guidelines, which would be incorporated into national licensing regimes for space activities.[114] Given that the IADC and ILA documents could be used as a starting point, consensus could be reached within a much shorter period.

While such documents would lack binding force, the hope is that they would naturally lead to the drafting of international instruments,[115] or through State practice crystallize into principles of customary international law.

In any case, it is clear that legal action is required sooner rather than later to preserve Earth orbit, and indeed the astronomical sky, for the use of future generations.

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[114] G Lafferranderie, 'Maintaining the Space Environment: Commentary Paper' in UN Office for Outer Space Affairs, *Proceedings of the Workshop on Space Law in the Twenty-First Century* (2000) 203, 206.

[115] Vladimir Kopal, 'Present International Law Principles Applicable to Space Debris and the Need for Their Supplement' in ESA, *Proceedings of the Second European Conference on Space Debris, ESOC,* (Darmstadt, Germany, 17-19 March 1997) 739, 744.

V. The relationship between space law and basic space science- a question of prioritization?

The above discussion has shown how provisions in the space law corpus can affect the conduct of basic space science in various ways; however, the points of application are *ad hoc,* drawing on discrete, specific provisions, rather than stemming from a broader, identifiable doctrine of 'protection of space science'. Space law and basic space science intersect only tangentially because there is no explicit hierarchy of space activities in space law. At the time of drafting of the outer space treaties, the overriding belief was that there was room for all possible space applications to coexist.[116] With the realization that certain aspects of outer space, for example radio spectrum, are indeed scarce resources, one becomes compelled to make a value judgment in allocating those resources between various space applications.[117] The only question is whether this value judgment is made explicitly or implicitly.

At present, the most significant space applications are undoubtedly civilian and military telecommunications, remote Earth sensing, location and positioning systems and meteorological satellites. It could well be argued that these infrastructures are of vital use to the 'international community',[118] and that priority should be given to them in the allocation of resources (radio spectrum, orbital slots). In the current system, this has been achieved *de facto* through the spectrum allocation practices of the ITU,[119] without great debate. Where does basic space science fit into this prioritization regime? How can astronomers and space scientists compete with such enormous commercial and military interests?

Hope may lie within the text of the Outer Space Treaty itself. Article I specifically guarantees freedom of scientific investigation in outer space, although this provision has generally been regarded as a statement of principle rather than one laying down concrete obligations.[120] If basic space science is to receive protection through some sort of prioritization, then perhaps this could be achieved through reinforcement of Art I by means of General Assembly Resolution (similar to the NPS Principles and Declaration on International Cooperation).[121] Such a resolution would be drafted by the LSC, and could refer to the need for radio spectrum reservation in favour of basic space science, or encourage the establishment of RQZs.

The above suggestion is reliant on the political will of States parties to recognize basic space science as being of importance to the international community. This is by no means certain, given the low profile space science enjoys in comparison to the 'big-ticket' space items such as communications and global navigation satellite systems. Thus it remains the task of space scientists worldwide to advertise the benefits of their work, to provide an impetus for substantive legal reform. This could

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[116] Hulsroj, above n 29, 110.
[117] Ibid.
[118] Ibid.
[119] Ibid. Military communications are even accorded absolute priority, exempted from co-ordination entirely.
[120] Cheng, above n 7, 252.
[121] Kai-Uwe Schrogl, 'Basic Space Science at UNISPACE III 1999' in UN Office for Outer Space Affairs, *Seminars of the United Nations Programme on Space Applications* (1998), UN Doc No A/AC.105/690, 141, 145.

occur, inter alia, through forums such as COPUOS,[122] or through initiatives such as the International Heliophysical Year.[123] There have been numerous proposals made for education and outreach activities to inform decision makers, as well as the general public, of the significance of basic space science.[124] The challenge is to break down the esoteric, 'ivory-tower' image and emphasize the importance of astronomy and basic space science in increasing our understanding of the world around us.[125] These areas have always been at the forefront of human wonder and philosophical thought, and hence of immense *cultural* value.[126]

It is important to note that progress is being made. The UNISPACE III conference report made note of the central role of space science in contributing to the 'future well-being of humanity',[127] as well as declaring that harmful interference with space science should be minimized wherever possible. COPUOS has undertaken discussions on space advertising and space debris. The efforts of space scientists to draw attention to their needs are being noticed slowly, if not spectacularly.

On a broader level, efforts are currently underway to draft an instrument on the ethics of outer space, for submission to the 33rd General Conference of UNESCO in 2005. The draft document, based on the recommendations of the Commission on the Ethics of Scientific Knowledge and Technology (COMEST) and the report of the Rapporteur of the former COMEST sub-commission on the ethics of outer space, aims to identify ethical (that is moral, as opposed to legal) issues related to the use and exploration of outer space. It is important to take ethical considerations into account because of the anthropocentric nature of outer space law. The interests of all nations and the maintenance of international security are at the focal point of the space law regime.[128]

The draft document refers to the freedom of scientific exploration, as declared in the Outer Space Treaty, as an underlying ethical principle that should guide the practice of States.[129] Furthermore, scientific data should be freely accessible by researchers and university staff in every country,[130] while commercial data may be protected according to 'commercial logic'.[131] States would be encouraged to take 'all appropriate measures' to give effect to these principles.[132]

The draft document draws our attention to a fundamental question of space use and exploration. Is the primary motivation the advancement of scientific knowledge,

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[122] Ibid.
[123] Planned for 2007, on the 50th anniversary of the launch of Sputnik I; <http://ihy.gsfc.nasa.gov/> (at 22 November 2004).
[124] See eg Cohen and Sullivan, above n 89, 343-392.
[125] D McNally, 'International Action' in Cohen and Sullivan (eds), above n 89, 23, 24.
[126] Woodruff T Sullivan, 'The Cultural Value of Radio Astronomy' in Cohen and Sullivan (eds), above n 89, 369, 371-2.
[127] UNISPACE III Report, above n 65, 47.
[128] Manfred Lachs, 'The Treaty on Principles of the Law of Outer Space, 1961-1992' (1992-3) 39 *Netherlands International Law Review* 300, 300-1.
[129] United Nations Educational, Scientific and Cultural Organization (UNESCO), *The Ethics of Outer Space: Policy Document* (2004) [1.3.7].
[130] Ibid [1.3.5].
[131] Ibid.
[132] Ibid [1.4.1].

is it conquest, is it resource exploitation?[133] Space exploration has been marked by the extreme dynamism with which the interests of States and private enterprises have shifted since the launch of Sputnik I.[134] Few would contest that space exploration offers unparalleled promise to make a positive impact on everyday lives. The key is to avoid repeating the mistakes of the past, allowing the 'greater good' to be obscured by the 'distortions and destruction' generated by the 'unbalanced relation among private, state and public interests'.[135] Perhaps it is only by adopting a value-oriented normative framework, with ethical considerations at the forefront, that the interests of 'humankind' as a whole can be served.[136] Science and ethics are closely related, and scientists should advance the argument that a 'just' priority of interests must recognize and protect the interests of science for the betterment of humankind.

In this context, the important role of developing nations should be mentioned. As discussed, basic space science has often served as a driving force behind national space programmes. The UN/ESA workshop series on basic space science has identified a three-stage process known as 'Tripod' for the accelerated implementation of basic space science activities.[137] The acquisition of research infrastructure allowing the taking of meaningful scientific data is the first step towards the establishment of an indigenous space science capability. The *Declaration on International Cooperation* specifically mentions the need for technical assistance in promoting the development of space science and space capabilities in interested States,[138] which could be of assistance to developing countries in attaining the critical mass required for such endeavours. It is in the interests of developing countries with space aspirations to advocate law reform protecting astronomical observations, to ensure that this crucial impetus is not lost. Such considerations are of importance to space science lobbyists, who need to find national delegates to represent their view in international forums such as COPUOS.[139]

VI. Conclusions

Space law is currently a small area of international law, but will grow in importance as improvements in technology allow more affordable access to outer space.

The current regime is characterized by the principle of *terra communis*, which encompasses the twin doctrines of freedom of use and non-interference in the use by others. This is reflected and expanded upon in the Outer Space Treaty, Liability Convention and other General Assembly Resolutions. The exposition and interpretation of these principles have important implications for the conduct of space science.

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[133] Ibid [3.1].
[134] Jose Monserrat Filho, 'Private, State and International Public Interests in Space Law' (1996) 12 *Space Policy* 59, 59.
[135] Ibid.
[136] Ibid 65.
[137] Hans Haubold and Willem Wamsteker, 'The UN/ESA Workshops on Basic Space Science in the Developing Countries' in W Wamsteker, R Albrecht and H J Haubold (eds), *Developing Space Science Worldwide: A Decade of UN/ESA Workshops* (2004) 3, 7-8.
[138] Article 5(a), (b).
[139] Andersen, above n 89, 18.

Scientific exploration has always been of importance to space exploration, and space law contains specific reference to the needs of science, most notably through Article I of the Outer Space Treaty. However, in practice, priority in allocating resources is accorded to commercial and military applications.

Legal developments in the next five to ten years will be critical for the future of astronomy and basic space science. With the increasing commercialization of the space industry, the interests of space scientists will in the future require protection through legal instruments. Their interests are to a certain extent incompatible with those of commercial space enterprises. This paper has identified two particular areas where urgent reform is needed. The international community is aware of these problems, and the United Nations has specifically recognized them through discussions in COPUOS and UNISPACE III. It has been suggested that a General Assembly Resolution be adopted expanding on Art I, explicitly recognizing the importance of basic space science and the need to protect it from competing applications.

It lies with the scientific community to press the case for increased recognition of space science. This paper has pointed to the legal, practical, cultural and ethical arguments that could be of assistance in attaining law reform. Space science has made crucial contributions to the advancement of human thought and scientists must not allow their work to be dismissed as esoterica. It can be hoped that their quiet but persistent efforts will lead to substantive law reform, allowing future generations to enjoy the intellectual and practical benefits of their work.

III. ENABLING TECHNOLOGIES

AMATEUR SATELLITES AS A VEHICLE FOR SATELLITE COMMUNICATION EDUCATION

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Abstract

At present, satellite communication is rarely pursued in laboratory exercises at educational institutions around the world. The idea that it is a prohibitively expensive venture contributes to the lack of such exercises. While this may be true for commercial endeavours, strictly educational pursuits of space-based communication are accessible to institutions and even individuals through the Amateur Satellite Service. It is thus proposed that this service be used as a means to acquire knowledge and skills in the field and subfields of satellite communication.

Introduction

Satellite communication necessarily finds its way into almost every space-based endeavour. From retrieving data on a science satellite orbiting Saturn to triggering distress signals in the middle of the Pacific Ocean, space-based communication is used in a plethora of applications. Meteorological satellites provide vital weather information, warning and protecting millions of oncoming disasters. Remote sensing satellites are able to scope arable land and aid in disaster management. The space sciences use telescopes and instrumentation aboard orbiting devices to test and explore the laws of nature. Global navigation satellite systems have made search and rescue, surveying and navigation not only easier, but in many circumstances possible. These applications have been realized because of satellite communication and those who design, build and operate satellites and their respective ground-based communication centres.

The engineers and technicians who perform these tasks require education in this discipline. There are many texts on the subject, and from a theoretical standpoint, teaching the topic is straightforward, though garnering practical experience in satellite communication is not. For many reasons, laboratory exercises regarding satellite communication are non-existent even in curricula at educational institutions in highly industrialized countries. Universities do not often have access to satellites or the means to license operators to communicate with them. Even if they did, rarely do they possess the resources to construct ground stations with commercial grade equipment to contact satellites.

For such institutions to offer practical satellite communication experience in the form of laboratory exercises, several conditions would need to be met. First it would be impractical for the majority of institutions to design and build the space portion (i.e. the satellite) for lack of time, expertise and funds. At the lowest level, satellites used in such an academic environment would therefore need to already be aloft and functioning and/or maintained by a third party.

Students learn much about satellites and satellite design when operating one from a proper ground station. In addition, ground station equipment would need to be easily accessible, maintainable and within the grasp of educational financial resources. These requirements are necessarily prohibitive in many cases; however, The Amateur Satellite Service is a system of satellites and information that overcomes these difficulties.

Implementation

It is not widely known that non-professionals have been designing, building and placing satellites in orbit for over 40 years. Launched on 12 December 1961, OSCAR-1 (Orbiting Satellite Carrying Amateur Radio) was placed into orbit a mere four years after the Russian satellite Sputnik 1. Shortly thereafter, the Radio Amateur Satellite Corporation (AMSAT - a 501(c)(3) non-for-profit educational organization) was founded and has since placed over two dozen communication satellites into earth orbit. The bulk of AMSAT's productivity is based on volunteer labour and donated resources to design, construct and, with the added assistance of government and commercial space agencies, successfully launch these satellites.[i]

The AMSAT service continues to provide access to space communication through the launching of new satellites and the maintenance of those already in orbit. The original AMSAT group (based in the United States of America) has inspired international groups of amateur radio operators to form like-minded societies and corporations for the promotion of amateur satellite communication. Among others, they exist in such countries as Chile[ii], France[iii], Germany[iv] and India[v], and are active in both the international and regional design, construction and support of satellites which are put into orbit with the express purpose of developing skills and knowledge in space technology and science.[vi] These satellites are available to use by anyone who holds an amateur radio license issued by the Government of a nation and are an untapped resource for teaching communications engineering and technology at the university level throughout the world.

One of the many hurdles in pursuing satellite communication, be it commercial, military or private in nature, is that of licensing bandwidth and operators in accordance with a country's communication laws. Regulations are formed by individual countries, but often aided by and in accordance with guidelines set by the International Telecommunication Union (ITU). Laws regarding the allocation of bandwidth present considerable political and financial difficulty to parties without a great deal of resources. Fortunately, these arduous tasks are circumvented through the use of the amateur radio service. The service already has allotted to it a band of frequencies and a well-organized structure for licensing communication equipment operation. Operating and licensing procedures differ between countries, so interested parties must consult their country's documentation, which is available either from countries' communication agencies or amateur radio organizations.[vii] In addition, only a nominal fee is required to apply for such a license and the application and test are sometimes free. Examinations are generally composed of a number of questions that concern basic operating procedures, rudimentary electronics theory and in some cases a Morse code test, all of which are easily learned within a reasonable period of time from readily available study materials.

The equipment used in contacting amateur satellites is considerably cheaper than those used in commercial environments. When redundancy and extreme reliability are not required, equipment used in ground segments of such stations need be no more expensive than what a university laboratory budget can afford. Simple satellite ground stations can be constructed for several hundred U.S. dollars and still serve as an adequate platform for educating technicians and engineers. A ground station costing a few thousand U.S. dollars would provide learning opportunities far beyond this. The principles of ground station design hold true for both commercial satellite communication ground segment endeavours and amateur ones. Thus, training garnered at the university level, or on one's own time, is directly applicable to industry and other higher order space-based communication activities.

General communications engineering materials[viii] and information specific to amateur satellites[ix] are easily obtainable. Educational institutions or individuals using textbooks regarding satellite communication might use amateur satellites to augment and enhance understanding of the subject. Communicating with satellites might even be used as the primary motivation for learning, in lieu of strictly paper-based, theoretical treatments of the topic. The World Wide Web is also a nearly inexhaustible source of information on satellite communication.

Space Segment[x]

Exemplary of AMSAT's current design and engineering efforts is the AMSAT OSCAR-E ("Echo") project. Upon its scheduled launch in June of 2004, it will provide amateur radio operators wonderful opportunities for basic education and experience in communications engineering.

Echo is a microsat-class Low-Earth Orbiting (LEO) satellite measuring 25cm on each edge. The cube is covered with solar panels on each side of a series of stacked aluminium trays. Combining both flight-proven and experimental technology, the six trays contain one or several of the satellite's sub-systems: the radio frequency (RF) receiver, the Integrated Flight Computer (IFC), the Battery Control Regulator (BCR), batteries, payloads, attitude controls and the RF transmitter.

The communications subsystems consist of four low-power, dual channel VHF FM receivers and two UHF FM transmitters feeding a phasing network and turnstile antenna providing the transmitter with up to +2dBic gain and 8W of power. The systems can provide both analogue and digital operation modes. Store and forward operation is planned for digital transmission at speeds from 300bps to 76.8Kbps using frequency-shift keying (FSK) modulation.

Echo's flight proven IFC provides satellite command and control functions. It is to be loaded with the Spacecraft Operating System (SCOS) which has served in all of the Amateur Radio microsat projects.

The satellite's six solar panels provide 20W of power to the spacecraft's subsystems including the BCR, which monitors and feeds a matched set of six 4.4Ah nickel-cadmium batteries. The battery subsystem nominally provides an 8V DC output.

An experimental active-magnetic attitude control system will be used to properly position Echo while in Low-Earth Orbit. The torquer rod and charging module making up this subsystem was designed by an AMSAT member for use on this satellite.

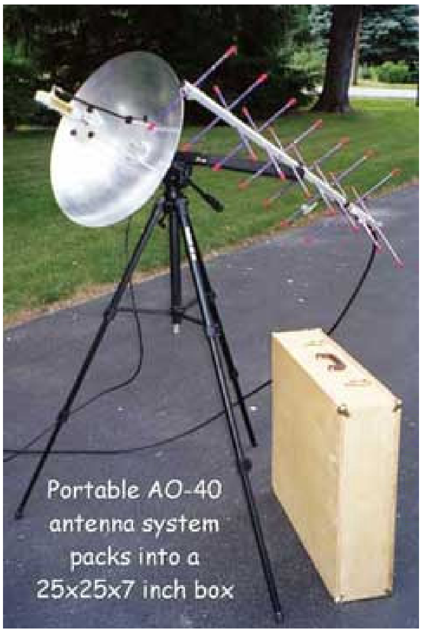

Figure 1 - Portable AMSAT communication station

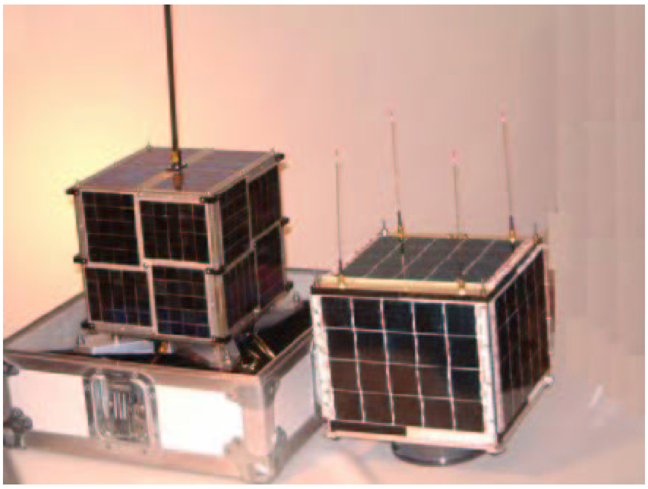

Figure 2 - AMSAT OSCAR-E "Echo" mechanical model (right) and original AMSAT Microsatellite model (left)

Several experimental payloads will also be aboard AMSAT Echo. The digital voice recorder is one such payload providing multiple channels of high-quality audio recording feeding the UHF FM transmitters.

Provided adequate funding is available, AMSAT OSCAR-E will be launched on a Dnepr LV (SS-18) rocket from the Baikonur Cosmodrome in Kazakhstan. It is the hope of the amateur radio community that Echo will be in service for intra- and inter-country communication and learning by the end of summer 2004.

Ground Segment

A vast range of equipment is available for use in contacting amateur satellites. The spectrum covers low-power handheld radios transmitting and receiving through manually-controlled beam antennae to commercial-grade communication transceivers pumping hundreds of watts into automated high-gain satellite dishes. It is a misconception that communication with orbiting satellites is expensive. One needs only meagre resources and ingenuity to perform basic satellite communication and not a great deal more to work with more advanced satellite functions. This is naturally extended from the operating principles of the amateur satellite community: providing space-based communication designed on a shoestring budget for people with a shoestring budget.

Figure 3 - The MOST Vienna ground station.

For a comprehensive list of resources and an introduction to simple ground station design, refer to *The Amateur Satellite Resource Guide*[xi] and *An Amateur Satellite Primer*[xii], respectively.

Research

Amateur satellite platforms and ground stations, in addition to being educational tools, have been successfully used in research programmes at universities around the world[xiii xiv]. An example of this is Canada's Microvariability & Oscillations of Stars (MOST) Space Telescope, which has a number of ground stations using amateur radio equipment to command and control an Earth-orbiting telescope. This basic space science experiment is a joint venture of Canadian Universities and the Canadian Space Agency. The ground station design team cites:

"The primary focus of our ground station design is to demonstrate that ground stations for scientific satellites can be built and maintained at low cost. The demonstration that such a station can operate reliably in an urban area at a fraction of the initial costs of a commercial station will be a great step forward in space research for notoriously under-funded academic institutions."[xv]

A research programme such as this might be tailored to accommodate an institution's needs and budget, just as it has in the case of the Canadian team. The MOST project shows that education in satellite communication may also be seen as a springboard for further application and technology development in space and incite all of the benefits thereof.

Conclusion

Due to limited financial and personnel resources, educational institutions around the world are rarely able to pursue satellite communication in a hands-on commercial environment. The use of amateur satellites as a vehicle for education alleviates the burden of placing devices in orbit, licensing operators and technology, finding expertise and securing copious funds for operations. Indeed, individual amateur satellite communication has been ongoing for decades and is thus well within the grasp of institutions or countries wishing to bolster capacity in this field. This may, in turn, lead to collaboration with other fields utilizing space-based communication in such disciplines as basic space science, meteorological science, and/or remote sensing.

A small investment in education reaps many tangible and intangible rewards for individuals, institutions and countries. The underutilized amateur satellite service provides a framework for this investment and is begging to be exploited for global education.

Acknowledgments

I sincerely thank Hans Haubold for our discussions and the encouragement and support he gave during the preparation of this document. He is an inspiration and his efforts are a boon to science and mankind alike.

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IV. CROSS-CUTTING ISSUES

WHAT IS THE INTERNATIONAL HELIOPHYSICAL YEAR (IHY)?*

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More than a celebration of the 50th anniversary of the International Geophysical Year (IGY), the IHY planned for 2007 will be a programme of coordinated research in the tradition of a long succession of international programmes, of which the IGY is arguably the most famous. One might justifiably ask, "Yet another coordinated research program? Given all the others, what will IHY have to offer? Will it lead to better science or just more science?" To address these and other questions, nearly 60 scientists participated in the United States Planning Workshop for the IHY from 20 to 22 April 2004 at the National Solar Observatory in Sunspot, New Mexico, USA. The workshop, organized into four working groups on the Sun, the heliosphere, magnetospheres and ionospheres, and atmospheres and climate, took up the challenge posed by these critical questions.

While IHY was listed as one of several I*Y programmes in a recent Eos article on the Electronic Geophysical Year (eGY), with the National Aeronautics and Space Administration of the United States (NASA) as its main sponsor, the sponsorship and roles of these programmes relative to each other have been evolving. Initial ideas about the IHY were confined to solar-terrestrial physics, which could fit under the umbrella of the International Polar Year (IPY) sponsored by the International Council for Science (ICSU). Strong voices on the workshop's scientific organizing committee, however, argued for a much broader purview of the IHY, out to the frontiers of heliophysical research in the same way that the IGY reached to the frontiers of geophysical research. At the workshop the broader purview was adopted as the starting point. It was agreed that the new word, "heliophysical," not to be confused with the more limited "heliospherical" (meaning primarily "solar wind"), should embrace not only atmospheric and solar-terrestrial physics but include studies of other planets, the outer reaches of the heliosphere, and its interaction with the interstellar medium. The IHY can thus establish and foster interdisciplinary ties with astronomy and astrophysics.

Adopting the broader purview has important implications for structure and funding. Unlike many of the other programmes, including the original IGY, the IHY will be a grass-roots, bottom-up rather than top-down, agency-sponsored programme. While this means that funding must be sought as a separate effort, the grass-roots approach will afford the freedom to focus on science rather than day-to-day mission-oriented activities. Adopting this approach also negates any perception that the IHY will be more US/NASA hegemony, a concern expressed at the workshop. Links with the international community will be nurtured through a variety of organizations including the International Astronomical Union, the International Space Science Institute, Committee on Space Research (COSPAR) and the United Nations. Nicola Fox of NASA's Goddard Space Flight Center reported on efforts to encourage projects involving scientists from emerging nations.

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A keynote address at the workshop given by George Siscoe of Boston University made clear that international programmes, beginning with the first IPY in 1882, each leave legacies as a direct result of their focused efforts. They organize and coordinate data gathering and analysis, provide thematic emphases, and justify resource allocations under those themes. Their objectives have evolved from mapping phenomena on Earth to mapping in three dimensions, adding data first from the upper atmosphere and then space, to analyzing system complexity to recognizing systems as integrated and interactive. Data gathering and analysis innovations have evolved from synoptic studies to coordinated data analysis workshops to numerical modeling and data assimilation. Siscoe offered two suggestions for IHY themes that were subsequently adopted. The first is comparative heliophysical studies, for example, of planetary magnetospheres and ionospheres from the Hubble Space Telescope. Comparative studies are a niche not currently filled by mission-oriented projects and could provide opportunities for scientists from emerging nations to join teams proposing for viewing time or support for data analysis.

The second suggested IHY theme in a sense encompasses the first: in keeping with plans to foster ties with astrophysics, it is to work toward making a universal science out of what we do by focusing on physical structures and processes that cross discipline lines rather than on individual phenomena as is traditional. For those who work in space physics, it represents a basic physics counterbalance to space weather, and it defines a new movement described in the report, "Plasma Physics of the Local Cosmos," recently published by the National Research Council of the United States. The motivation for this movement comes from a statement by E. N. Parker in his book, *Cosmical Magnetic Fields*:

> "It cannot be emphasized too strongly that the development of a solid understanding of the magnetic activity, occurring in so many forms in so many circumstances in the astronomical universe, can be achieved only by coordinated study of the various forms of activity that are accessible to quantitative observation in the solar system."

Progress toward that end can be made with cross-disciplinary, intercomparative studies of processes like reconnection, explosive energy conversion, generation of energetic particles, cross-scale coupling and turbulence, and of structures like flux ropes, current sheets, shocks and waves. Following Parker, Siscoe noted that these processes and structures fall into the category of magnetically organized matter, as distinct from gravitationally-organized matter like planets, stars and galaxies.

Speaking on behalf of participants in the working group on atmospheres and climate, Marvin Geller of the State University of New York noted they were the only group present addressing gravitationally-organized matter. Nevertheless, the group became an integral part of the workshop effort and enthusiastically provided input for potential IHY projects on Sun-atmosphere connections. These fall into long- and short-term categories. Since climate studies rely on decadal or multi-decadal data, long-term IHY projects cannot be data-gathering campaigns. Instead, the group proposed much needed assessments of scientific understanding in several areas, including irradiance reconstructions over multi-century time scales, the role of the Sun in producing tropospheric/stratospheric climate variability, the response of stratospheric ozone to solar variability over the solar cycle and cosmogenic proxies as indicators of solar activity on time scales from a solar cycle to millennia. For short-term projects, the group made a list of eight candidate campaigns involving theoretical, observational, numerical and laboratory studies, for example, on the effect of cosmic rays on ion nucleation, aerosols, clouds and climate.

The working group on magnetospheres and ionospheres proposed to implement two major IHY thrusts that would integrate theory and modelling with observations and leave as a legacy the elevation of modelling to a mature research tool. Supporting the concept of comparative planetary studies, one thrust would focus on areas like auroral dynamics, storms, substorms and radiation environments at different planets. Another thrust would focus on the end-to-end solar-terrestrial system. A prime example is the real-time global ionosphere campaign proposed by Tim Fuller-Rowell of the University of Colorado / Space Environment Center of the National Oceanic and Atmospheric Administration of the United States (NOAA)) to characterize global ionospheric variability as a function of season and geomagnetic activity. The campaign would reflect IHY priorities in several ways: It would cut across disciplines from solar to lower atmospheric physics; require data from many countries; address a global problem with high fidelity; have potential for discovery; and supply Global Positioning System (GPS) to developing countries.

The suitability of global studies using widespread arrays of low-cost, ground-based instrument packages was echoed in other groups, notably in the working group on the heliosphere. Establishing a network of muon-monitors and increasing neutron monitor coverage to gain latitudinal and longitudinal resolution were among the proposed possibilities. At the lowest end of the cost scale, Justin Kasper described unique plans for thousands of low-frequency radio receivers. Like pixels in a snapshot, these could image the Sun and track evolving structures in the solar wind as they head toward Earth, while their Faraday rotation capabilities could map ionospheric parameters in unprecedented detail. Doing IHY science with widespread ground-based arrays has the added benefit of providing multi-national educational opportunities. These would involve real-time data collection that could be incorporated into science programmes around the globe.

The working group on the heliosphere also compiled a list of science questions concerning gaps in the overall understanding of our home star system and designed potential IHY campaigns to address those questions. Primary among them is a 3-dimensional comparative study of the upcoming solar minimum with the previous one of opposite magnetic polarity. Using data from the existing spacecraft fleet, which constitute a formidable heliophysical observatory, and working synergistically with the proposed network of small ground-based facilities, the study would create an unprecedented legacy data set completing the 22-year solar cycle. Another campaign would create a bridge to proposed atmospheric campaigns on the role of cosmic rays both in creating signatures of long-term climate variations and in controlling atmospheric parameters. A campaign to understand solar wind signatures of reconnection would create a bridge to solar physics and reflect the theme of universal processes.

The theme of universal processes became the centrepiece of the report from the working group on the Sun. Terry Forbes and Sarah Gibson summarized their efforts in a chart, shown below, that indicates processes common to an array of solar-related phenomena. In addition, the group proposed a number of potential IHY campaigns, some calling for much-needed coordination among existing ground-based observing facilities. For example, Ron Moore proposed using the widely available H-α telescopes to address the perplexing problem of why some filaments fail to erupt.

E: established
S: speculative

PROCESSES	Coronal Mass Ejections (CMEs) & flares	solar wind	solar cycle	granulation	cosmic ray modulation	irradiance
reconnection	E	E	S	S	E	
particle acceleration	E					
shocks & waves	E	E			E	
dynamo			E	E		E
turbulence/convection	S	E	E	E		E
multi-scale structures	E		S		E	
energy storage & release	E					
radiative transfer						E

PHENOMENA

All groups stressed the importance of working through existing programmes like Climate and Weather of the Sun-Earth System (CAWSES) and groups like Coupling, Energetics and Dynamics of Atmospheric Regions (CEDAR), Geospace Environment Modeling (GEM) and Solar, Heliospheric and Interplanetary Environment (SHINE), of maintaining existing spacecraft missions, and of promoting the development of comprehensive, long-term databases. All agreed to incorporate eGY as an intrinsic legacy tool. While the IHY will focus on campaigns that can be carried out during the celebratory year 2007; just as in previous international years, IHY activities will leave a foundation for future science and understanding.

Immediate follow-up to the workshop will include three special sessions at Fall Meeting of the American Geophysical Union (AGU) on universal processes and structures, low-cost distributed instrument arrays, and education outreach opportunities.

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