BGUSAT as a remote sensing research platform

Dan Blumberg, Shimrit Maman

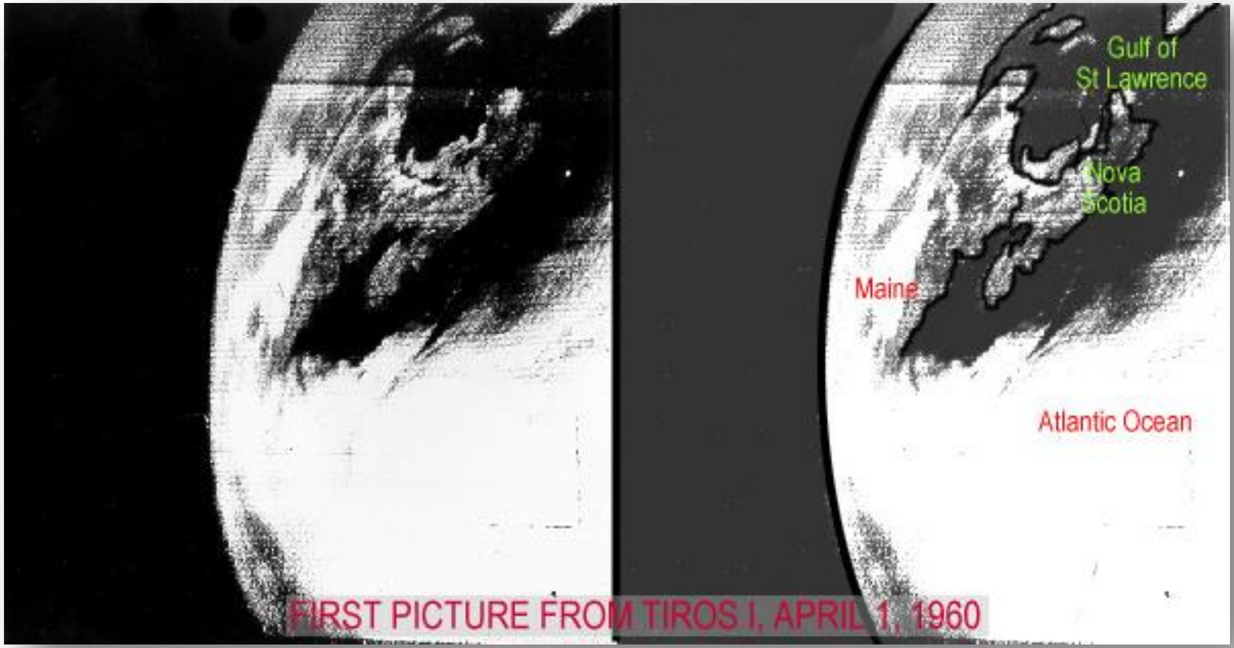
Aviran Sadon, Colin Price

IAI MBT Space division

BEN-GURION UNIVERSITY OF THE NEGEV
THE EARTH AND PLANETARY IMAGE FACILITY

Satellite Remote sensing

Imaging from space is very common

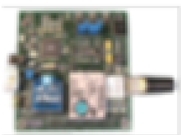


TIROS-1,

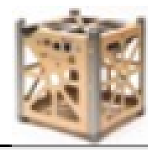
US meteorological satellite, first satellite to be launched for the declared purpose of earth observations.

BGU SAT | BEN-GURION UNIVERSITY OF THE NEGEV
THE EARTH AND PLANETARY IMAGE FACILITY

Spacecraft miniaturization trends



PCBSat



CubeSat

PICOSat

1-100g	0.1–1kg	1-10kg	10-100kg	100-500kg
£100-1000	£10-100K	£1-2M	£1-10M	£10-50M
Femtosatellite	Picosatellite	Nanosatellite	Microsatellite	Minisatellite

ChipSat

PalmSat

Snap-1

UK-DMC

Objectives

Technology capability demonstration

(ESA's PROBA program, NASA's Edison and Franklin programs)

Education

(MIT Spheres, Stanford Gravity Probes): Used in universities to teach their students the **fundamentals of satellite engineering** and project management using **hands-on experience**.

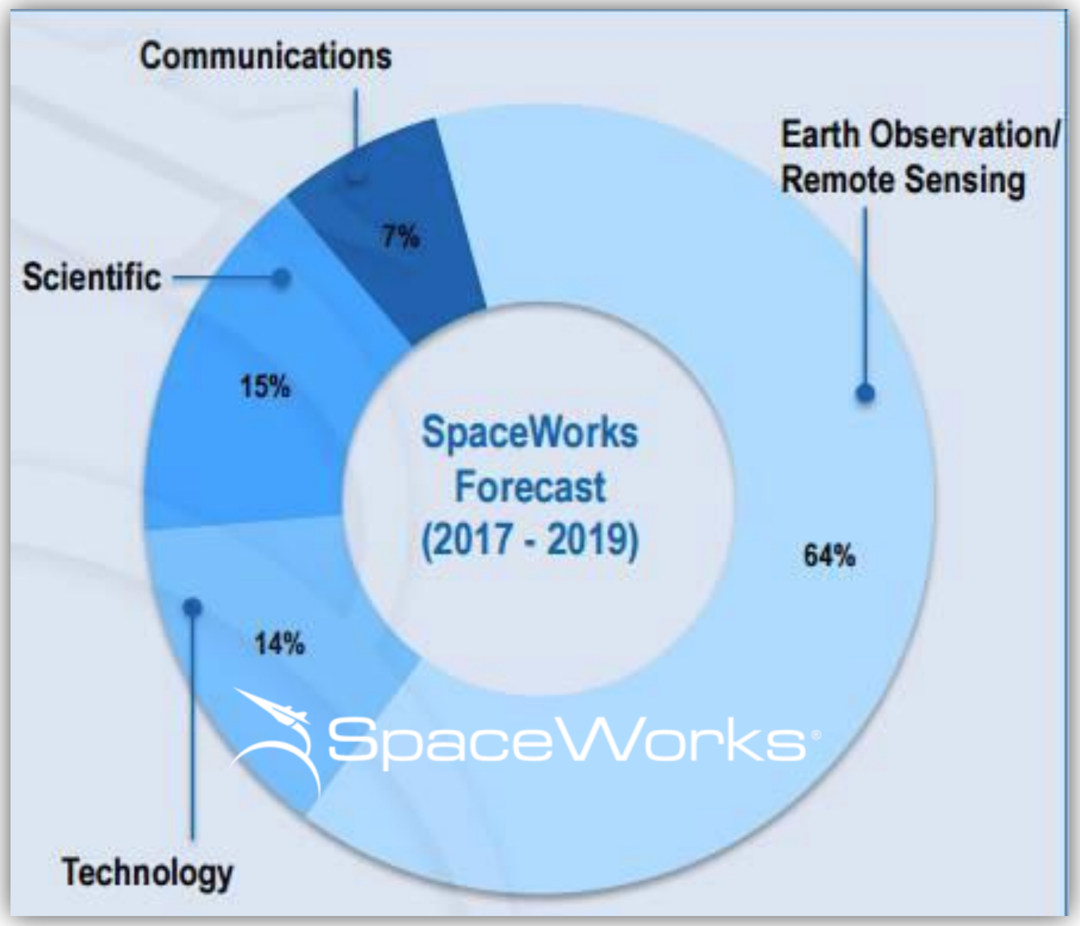
Cubesats are designed, built, tested, and launched by universities at a price between $50,000 and $200,000 *(Bouwmeester & Guo, 2010).*

BGU SAT | BEN-GURION UNIVERSITY OF THE NEGEV
THE EARTH AND PLANETARY IMAGE FACILITY

Science in a box

- Education and\or capability demonstration is the primary objective in most missions.
- Researchers understood the potential quality of the science that could be achieved using constellations of Cubesats.
- Science started as a secondary objective in most Cubesat programs! (might explain the lack of publication)

SpaceWorks Enterprises forecast



Remote sensing the next generation?

בשנים האחרונות ישנם פרויקטים בתחום הננו לוויינים
בעלי מטע"דים לחישה מרחוק של כדור הארץ

סקר מקיף המעריך את **היכולות האפשריות** של:

Earth observation from CubeSats

(Selva and Krejci, 2012)

BGU SAT | BEN-GURION UNIVERSITY OF THE NEGEV
THE EARTH AND PLANETARY IMAGE FACILITY

Remote sensing the next generation?

Can Cubesats by themselves do world-class Earth science?

should cubesats stay primarily focused on educating students in universities?

What capabilities are currently under development?

What capabilities have already been demonstrated?

What limitations do Cubesats have that prevent high performance in Earth Science?

Which scientific applications are most affected by these limitations?

BGU SAT BEN-GURION UNIVERSITY OF THE NEGEV
THE EARTH AND PLANETARY IMAGE FACILITY

“Missions with highest performance”

Table 1
List of Earth observation Cubesat missions in chronological order.

Cubesat	Institution	Payload	Measurements	Launch date and status	Reference
QuakeSat	Stanford University and Quakesat LLC	AC magnetometer	Ultra low frequency (ULF) magnetic signals from large (Richter >6) earthquakes	2003 (success)	[26]
ION	University of Illinois at Urbana-Champaign	Photometer (Photomultiplier Tube) and 640×480 pixel CMOS color camera	0.76 µm oxygen emission band in the 100 km upper atmosphere	2006 (launch failure)	[27]
CanX-2	University of Toronto	Atmospheric spectrometer, and GNSS receiver in occultation geometry	1-km horizontal resolution tropospheric CO_2 total column Atmospheric humidity and total electron content	2008 (success)	[4]
SwissCube-1	Polytechnic School of Lausanne	Passive optical telescope, with 188×120 pixel camera	0.76 µm oxygen emission band in the 100 km upper atmosphere	2009 (success)	[28]
Micromas	Massachusetts Institute of Technology	mm-wave multi-channel radiometer	Hyperspectral microwave atmospheric sounding (vertical profiles of atmospheric temperature and humidity)	In development	[5]
Cloud Cubesat	NASA Goddard Space Flight Center (GSFC)	VIS camera NIR camera Polarimeter	Aerosol and cloud properties	In development	[6]
M-Cubed (Michigan Multipurpose minisatellite)	University of Michigan	25.4 mm aperture, 17.6 mm focal length telescope, with 1628×1236 pixel CCD	Medium resolution optical imaging (200 m)	In development	[29]
Aalto-1	Aalto University	5–10 nm, 6–20 channel imaging VNIR Fabry–Perot interferometer spectrometer	Aerosol and cloud properties, vegetation measurements, fire monitoring, water monitoring, land use, atmospheric chemistry	In development (launch targeted 2013)	[30]
FireFly	NASA GSFC	VLF receiver, photometer	Lightning detection	In development	[31]

(Selva and Krejci, 2012)

RS from cubesats

- Cubesats with **some** Earth observation capability have been developed in the last years
- most of them carry space weather sensors, or modest resolution optical cameras
- Some technologies are more appropriate than others for use in Cubesats, arguably because they are more prone to miniaturization

BGUSAT

Mission type	Earth observation Technology
Operator	ISA/Ben-Gurion University of the Negev
Spacecraft properties	
Manufacturer	IAI Ben-Gurion University of the Negev
Launch mass	5 kilograms (11 lb) [1]
Dimensions	30 x 10 x 10 cm (3U cubesat)
Start of mission	
Launch date	15 February 2017 3:58 UTC [2]
Rocket	PSLV-C37
Launch site	Sriharikota Launching Range
Contractor	ISRO
Entered service	15 february 2017 3:58 UTC [2]
Orbital parameters	
Reference system	Geocentric
Regime	LEO
Perigee	505 km
Apogee	505 km

BGUSAT
BEN-GURION UNIVERSITY OF THE NEGEV
THE EARTH AND PLANETARY IMAGE FACILITY

BGUSAT

- In the past four years, BGUSat has progressed from a student and researchers educational tool to a research platform demonstrating technology and scientific instrumentation!
- 15.2.2017!
- During this period many interdisciplinary projects were conducted and a firm knowledge infrastructure was established

BEN-GURION UNIVERSITY OF THE NEGEV
THE EARTH AND PLANETARY IMAGE FACILITY

PSLV C-37

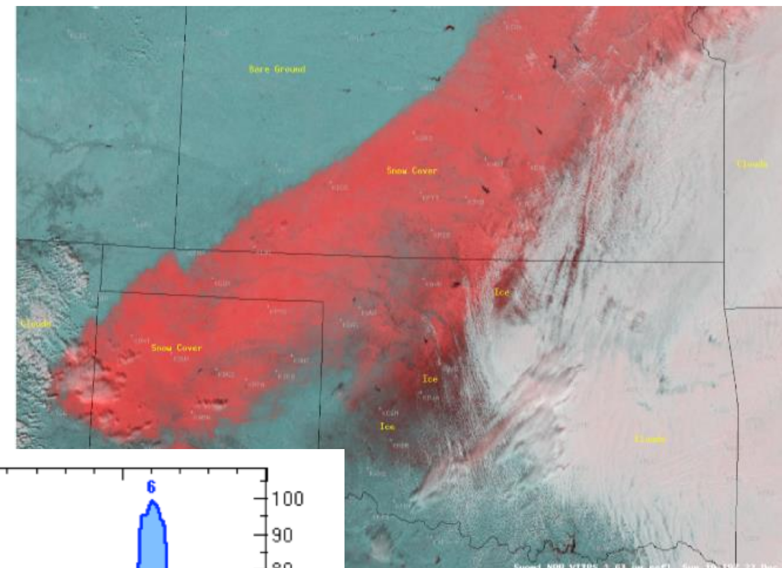
- 104 satellites
- Cartosat being the main spacecraft

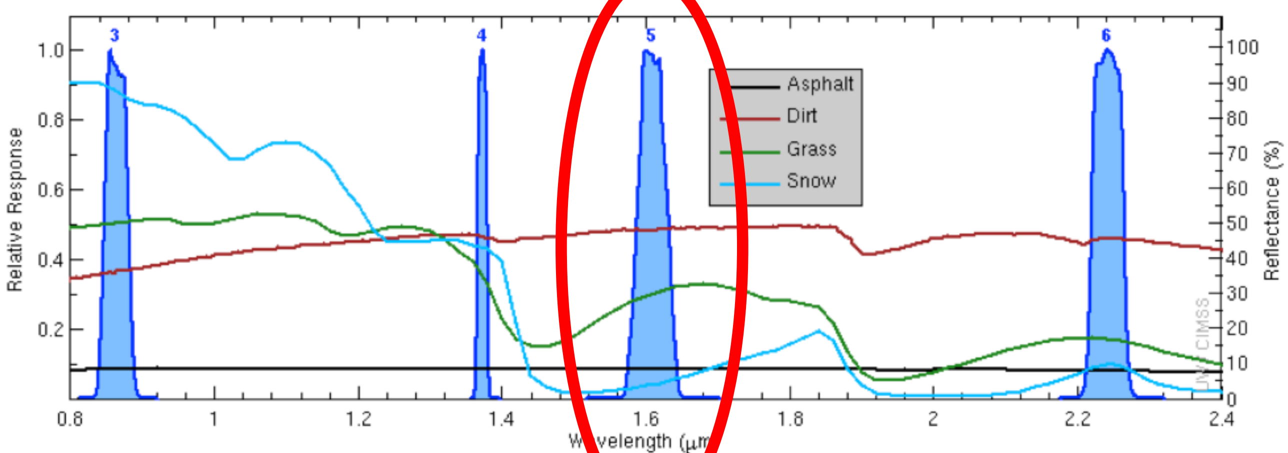
Cartosat

इसरो isro
nrsc
First day Image of Cartosat-2 Series
Part of Busto Arsizio, Italy
Acquired on 18-02-2017
Cartosat-2D
Panchromatic 0.60m
Scale 1 : 4000
NRSC / ISRO

Imaging in Short-Wave InfraRed (SWIR)

- snow, ice and cloud discrimination
- Sensitivity to CO2
- Sensitivity to Earth Glow
- Seeing through haze





IE NEGEV
E FACILITY

Images courtesy: http://www.sensorsinc.com/gallery/images

BGUsat Imaging in Short-Wave InfraRed (SWIR)

Visible Wavelengths (400-700 nm)

SWIR Wavelengths (1500-2500nm)

Strong Ability to See Through Scattering Media (Haze, Smoke)

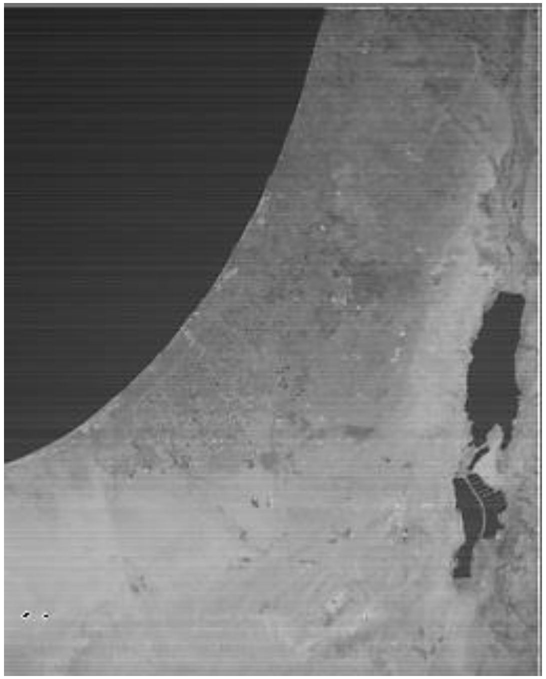
Images courtesy: http://www.sensorsinc.com/gallery/images

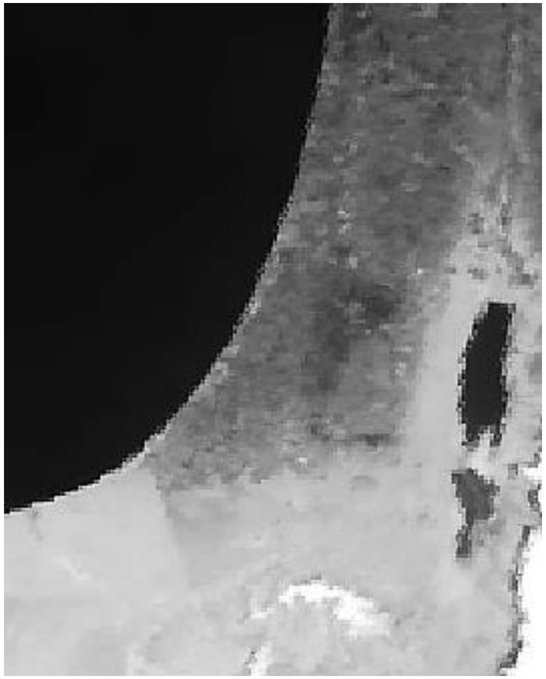
Technical characteristics

Satellite Name	Band	Bands in SWIR	Swath Width	SPATIAL RES'(m)
BGUsat		1.55-1.7 µm	224km	600
NOAA AVHRR/3	3A	1.64 - 1.58	2900km	1000
WorldView 3	2-3	1.546µm - 1.686 µm (40nm for band)	13.1km	3.7
Landsat 4-5	5	1.55-1.75	185km	30
Landsat 7	5	1.55-1.75	185km	30
Landsat 8	6	1.651 - 1.566	185km	30
Hyperion	B141-B161	1.558 - 1.790 µm	7.5km	30
Sentinel-2MSI	11	1.61	290km	20
EO-1 ALI	5	1.55 - 1.75 µm	37km	30
EO-LAC	1	0.89-1.6 µm	185km	250
Aster	4	1.600 - 1.700 µm	60km	30
Modis	6	1.628 - 1.652µm	2330 km	500

THE EARTH AND PLANETARY IMAGE FACILITY

May images of BGUSAT vs NOAA

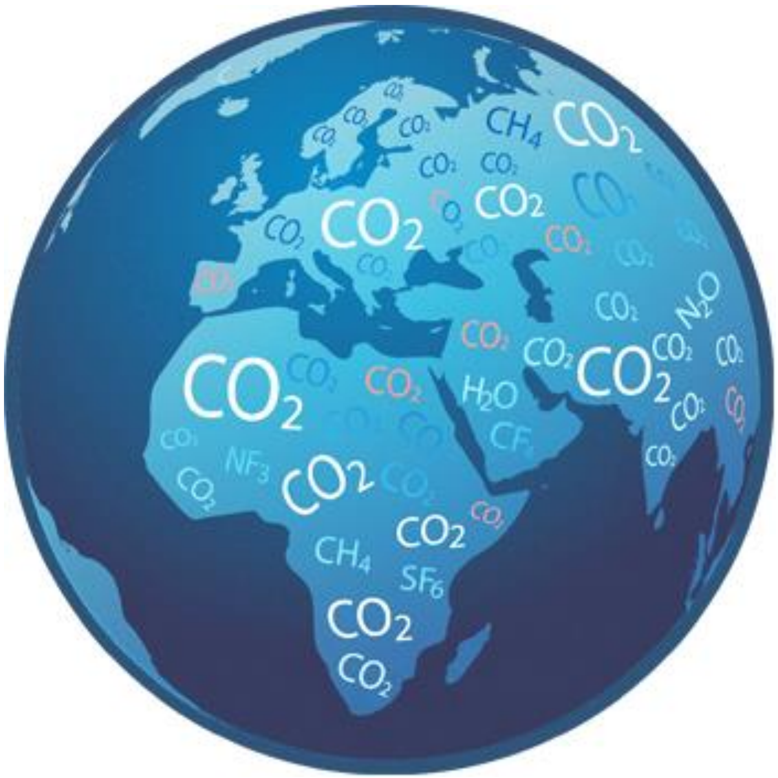


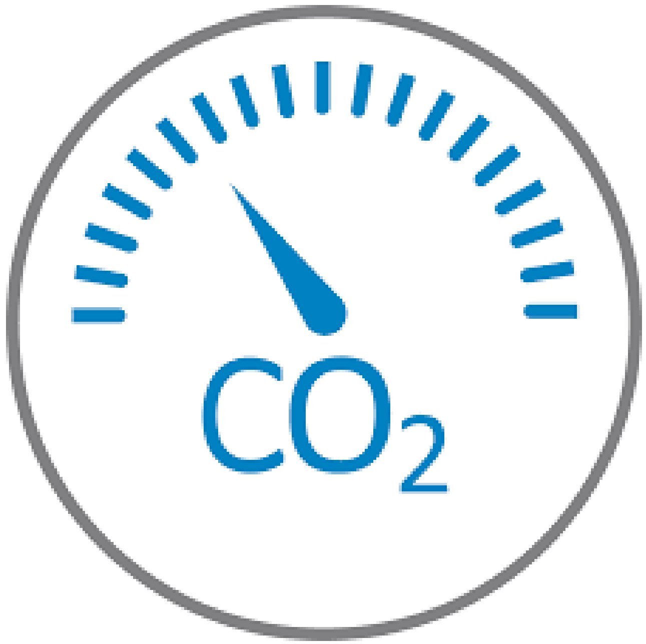


BGUSAT images ☺

BGU SAT | BEN-GURION UNIVERSITY OF THE NEGEV
THE EARTH AND PLANETARY IMAGE FACILITY

Ongoing Research





Earth's airglow layer

Photographed from the ISS

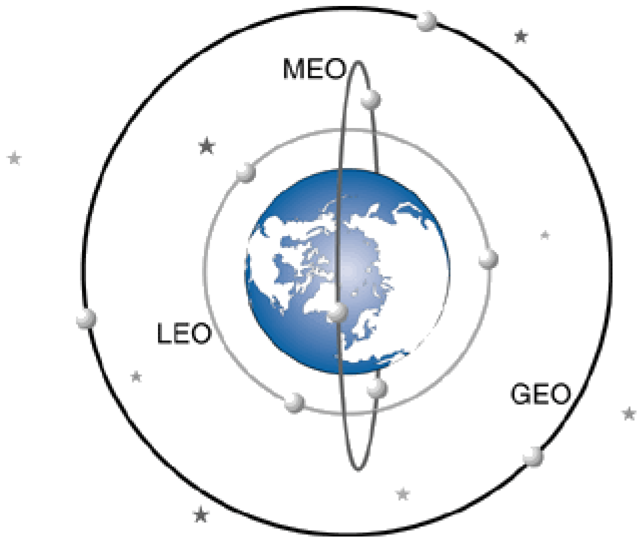
Combining LEO & GEO

CubeSats for RS missions promise to combine:

Temporal resolution of GEO missions

+

Spatial resolution of LEO missions



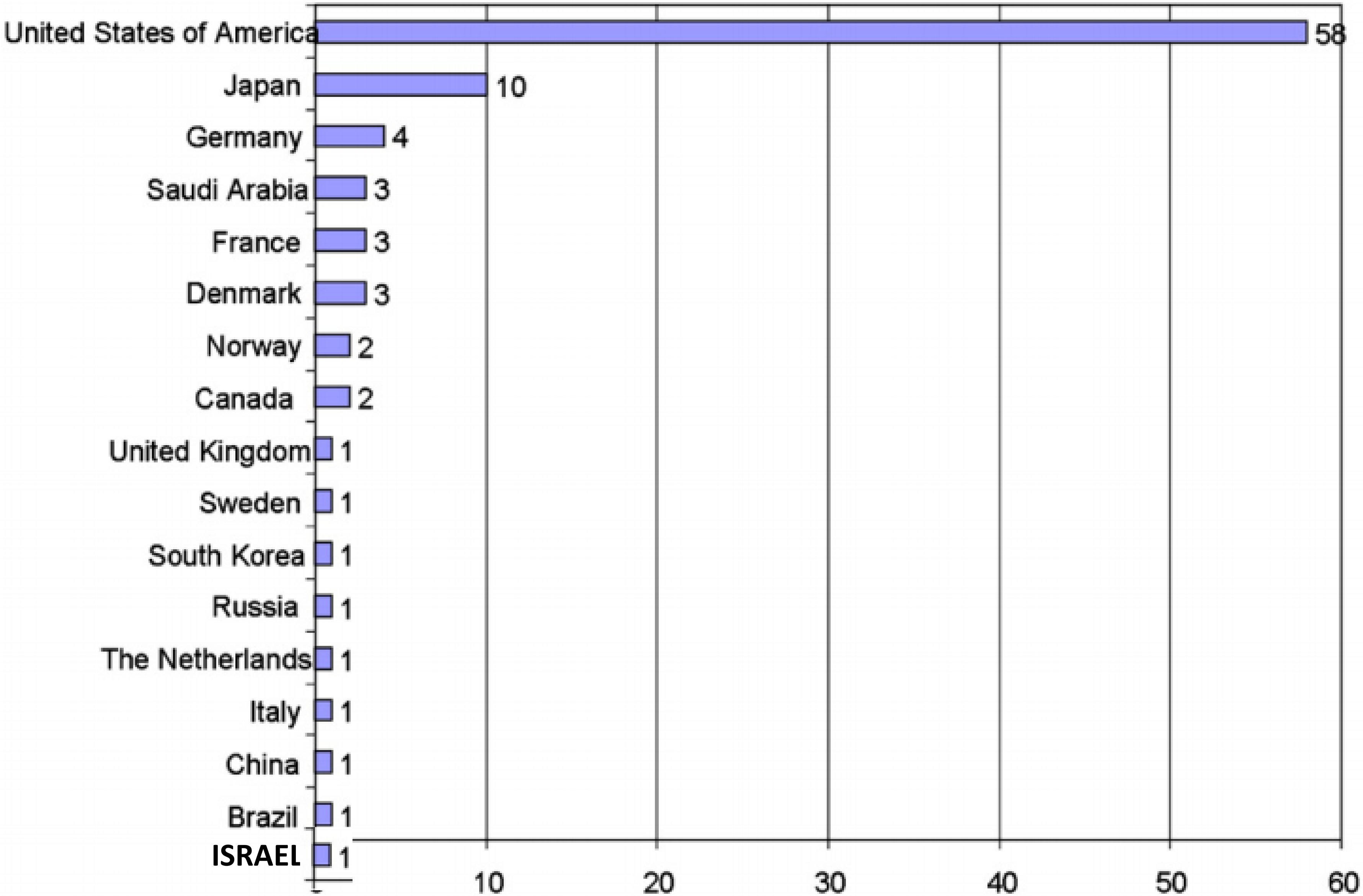


Fig. 3. Geographical distribution of pico- and nanosatellite developers.

Thank you!

BGU SAT | BEN-GURION UNIVERSITY OF THE NEGEV
THE EARTH AND PLANETARY IMAGE FACILITY

Concluding remarks