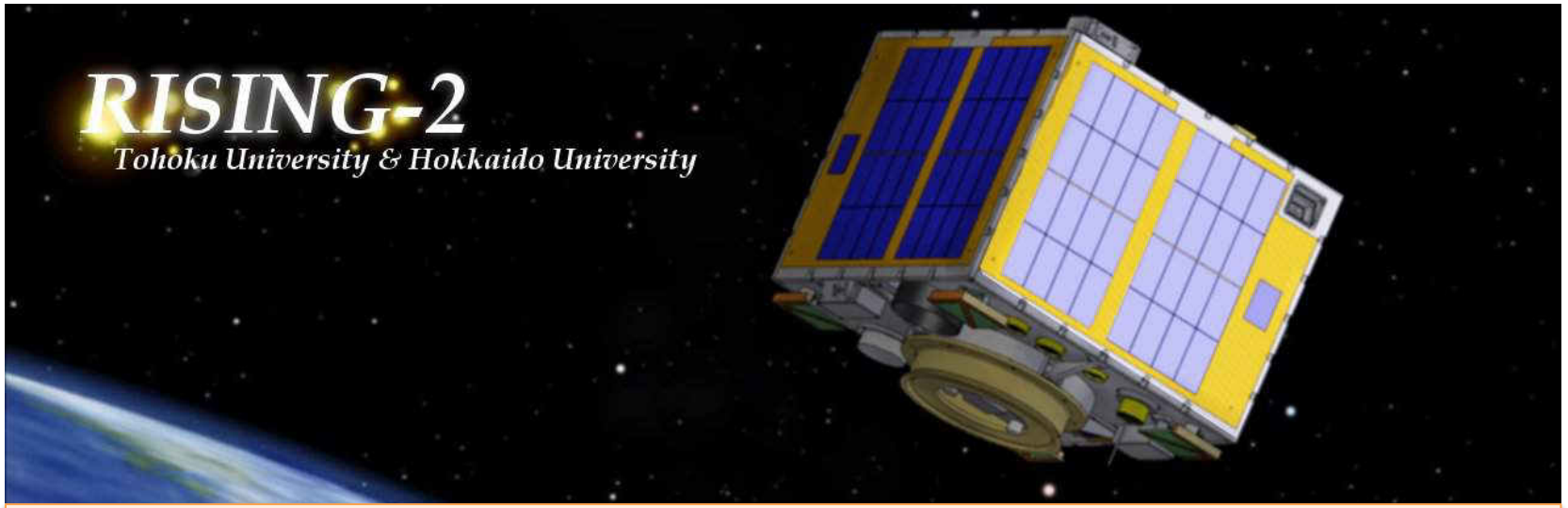
Geo Smart Asia 2016, Kuala Lumpur, Oct. 18. 2016



Great Possibility of Micro-satellite

high-quality, cost effective imaging
with advances in sensor technology

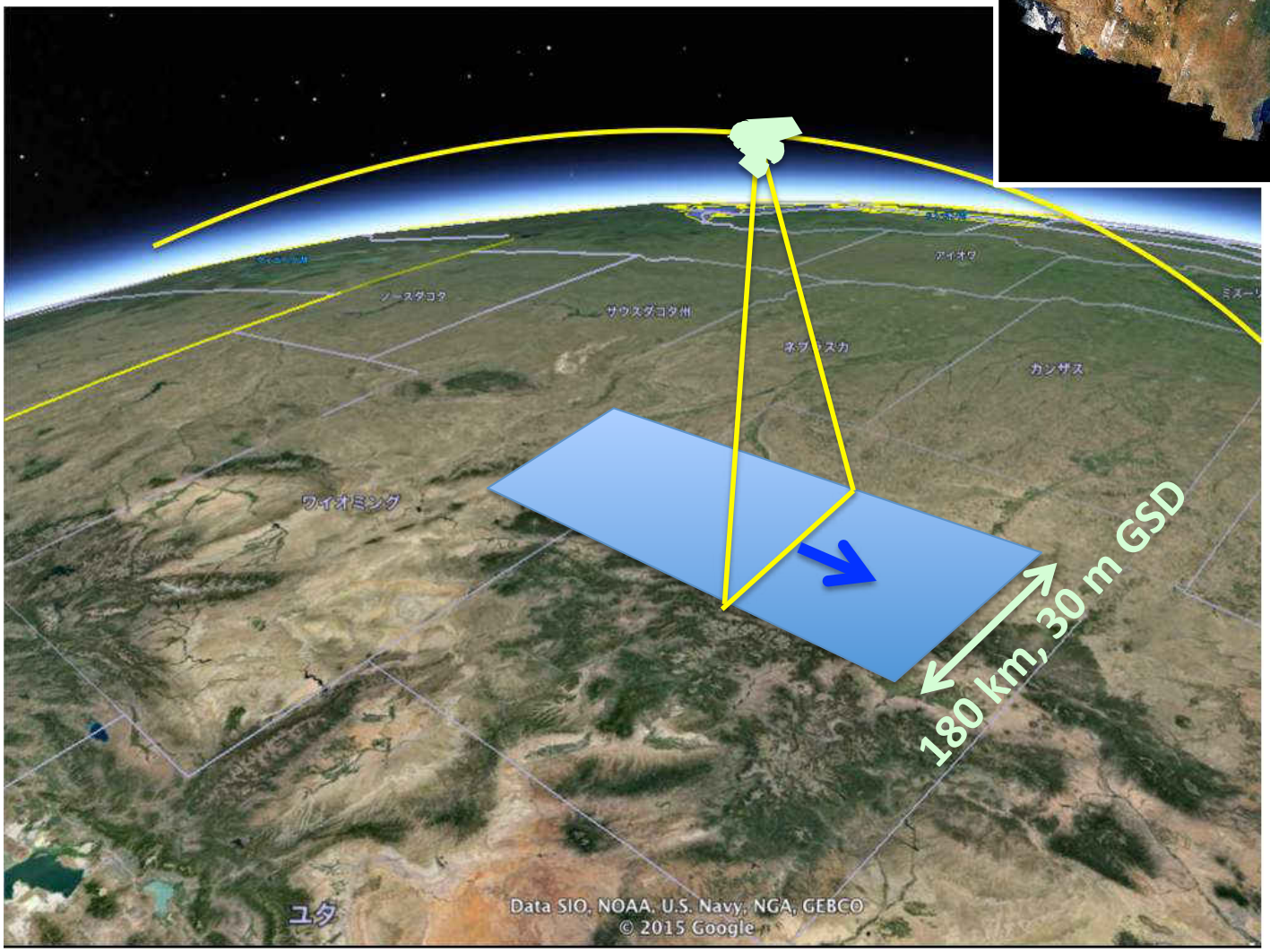
Yukihiro Takahashi
Space Mission Center (SMC)
Creative Research Institution (CRIS)
Hokkaido University

Problem of remote sensing with satellite

- Long re-visiting interval (ex. 16 days for LANDSAT-8)
- Low reliability of obtained information with limited filters

- daily visiting by target pointing and constellation
- improvement of reliability by detail spectral measurement

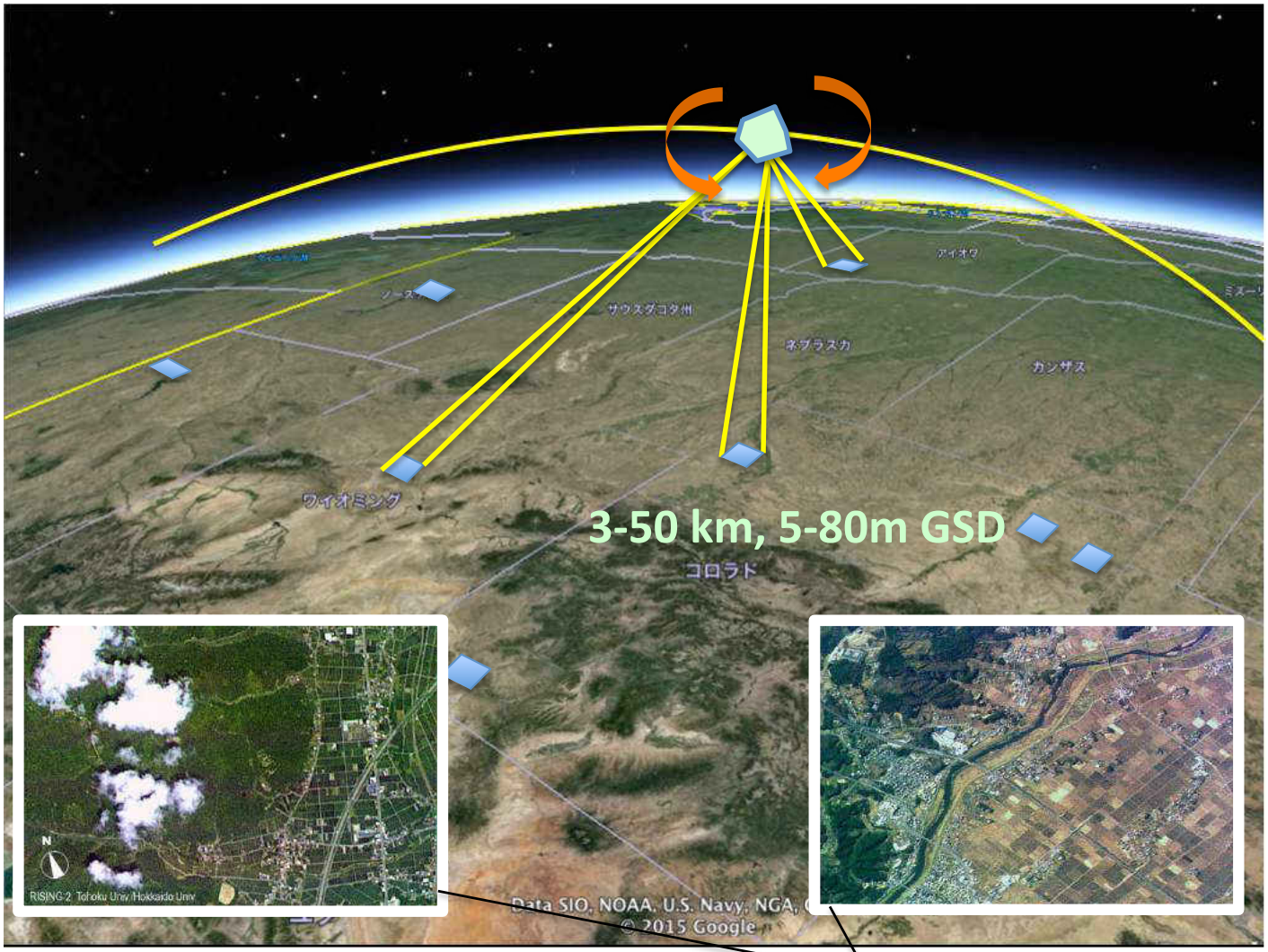
LANDSAT-8: pushbroom imaging



revisiting period: 16 days

Multi-point imaging by rapid target pointing

(actual coverage is 10-20 times larger than LANDSAT-8)



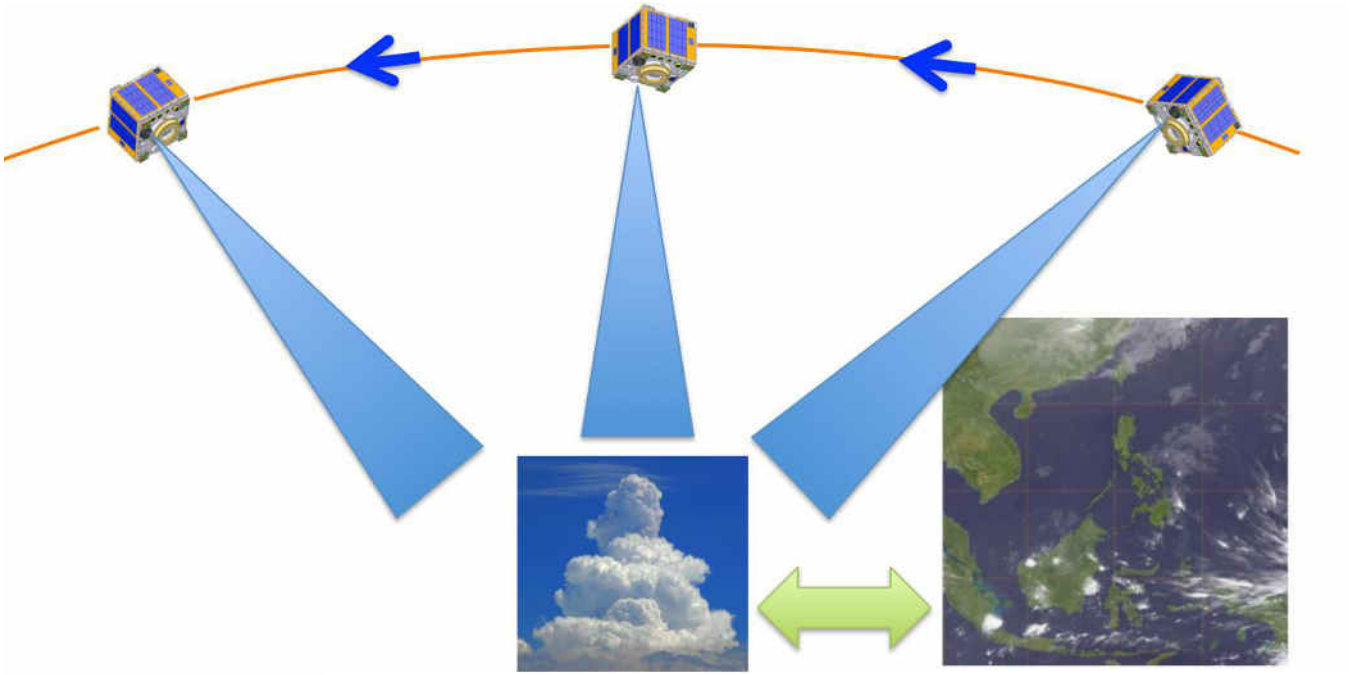
Images taken by RISING 2

daily visiting

Target Pointing by precise attitude control

... most of big satellites make pushbroom scan
by orbital motion...**1 time / 16 days**

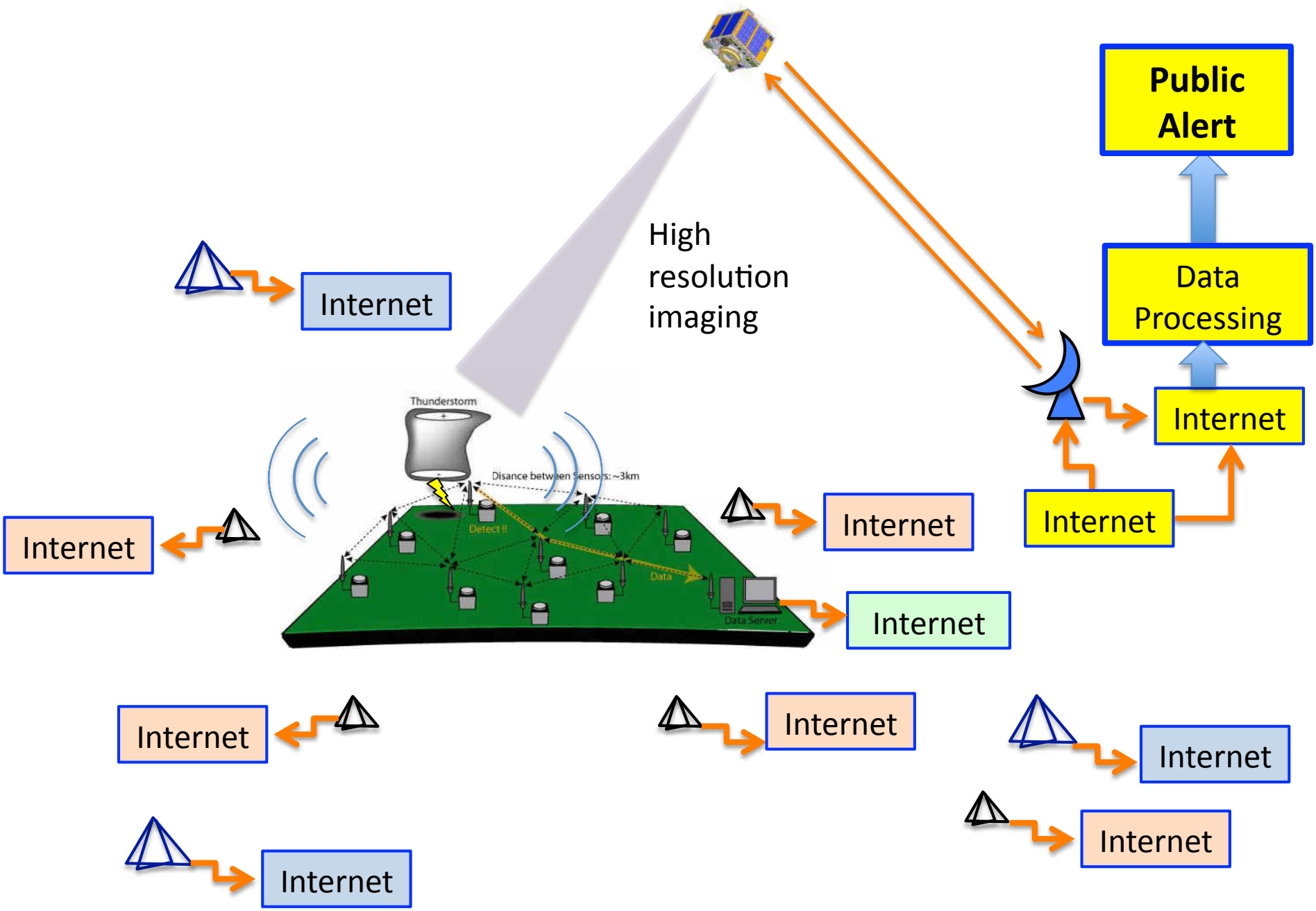
- Flexible on-demand operation
  covering from nadir to horizon (>5000 km in diameter)
  enables frequent visiting (**2 times / day** in daytime)
- Multi-band imaging and long exposure time



10m resolution by micro-sat.

0.5-1km res. by meteorological sat.

Active operation of satellite for disaster

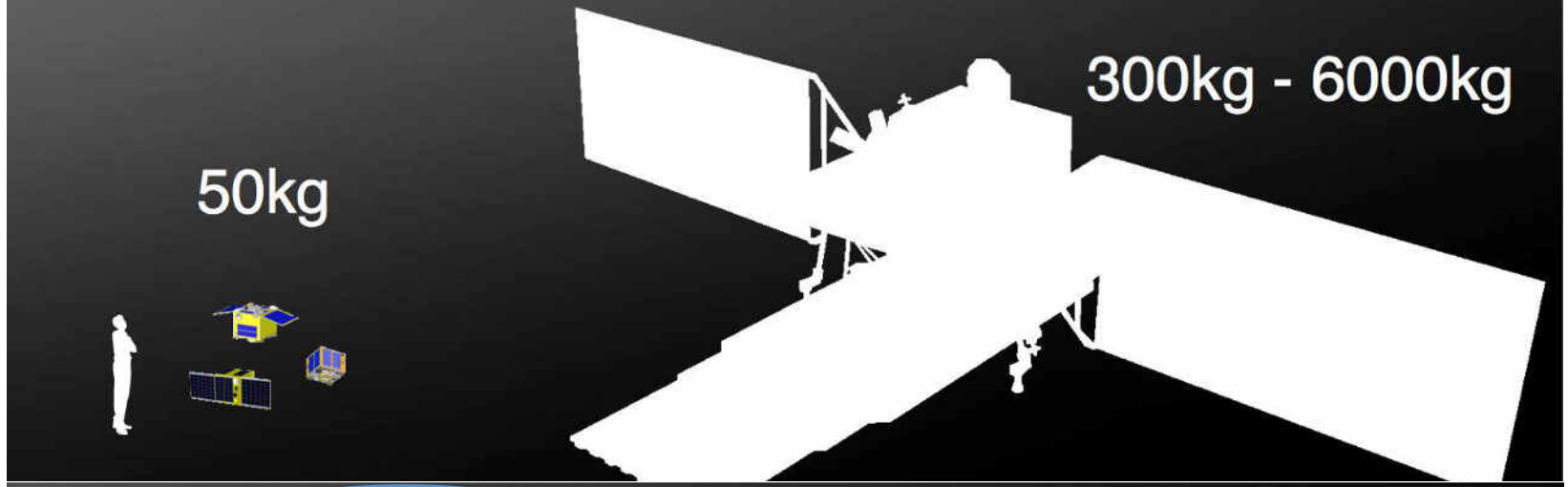


Personal computer

Micro-satellite

Super computer

Larger-satellite



3-5M USD

> A few 100M USD

Quick fabrication (One year)

Long period (>10years)

On-demand operation based on User's purposes

To carry heavy equipments

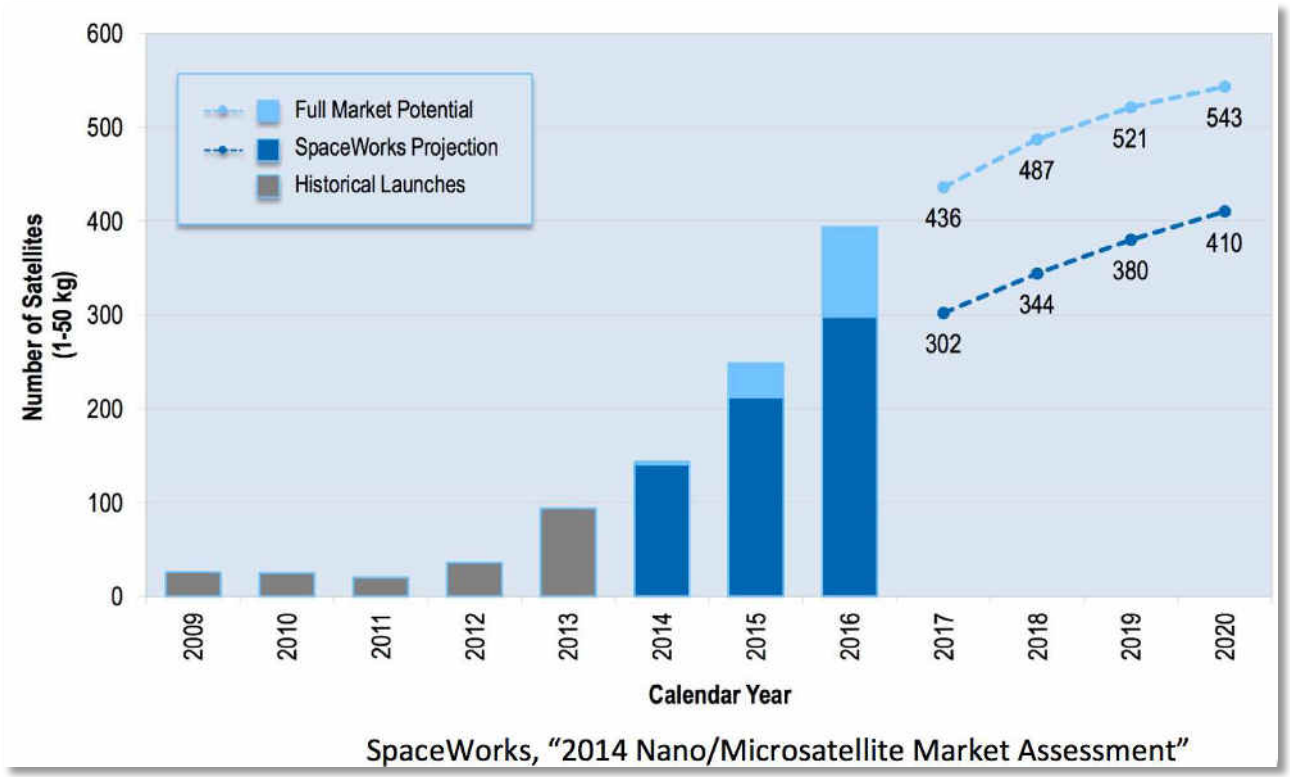
GiFT

Micro-satellite is becoming operational tool

Nano-/Micro-satellite is the world trend in space development...

It's not only educational/experimental tool, but operational device.

HP of SCIENCE



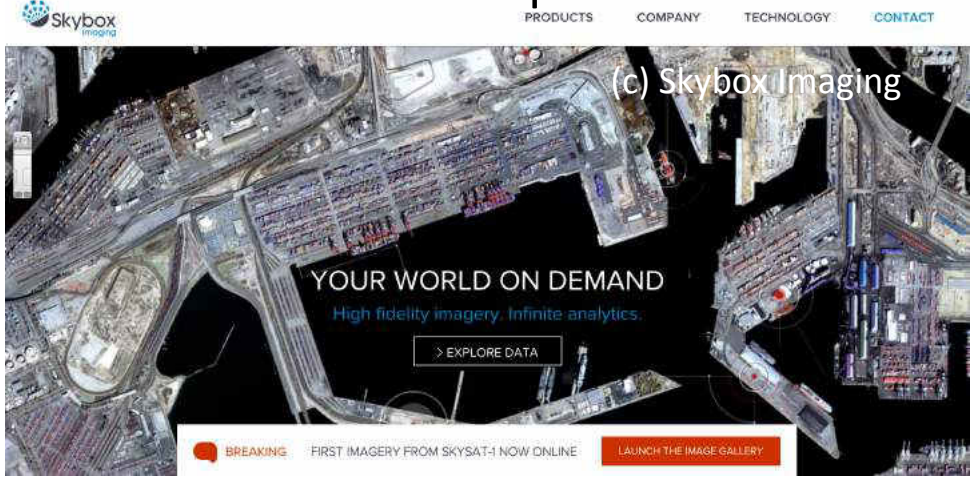
SpaceWorks, "2014 Nano/Microsatellite Market Assessment"

Drastic increase of operational micro-/nano- satellite will come in a couple of years

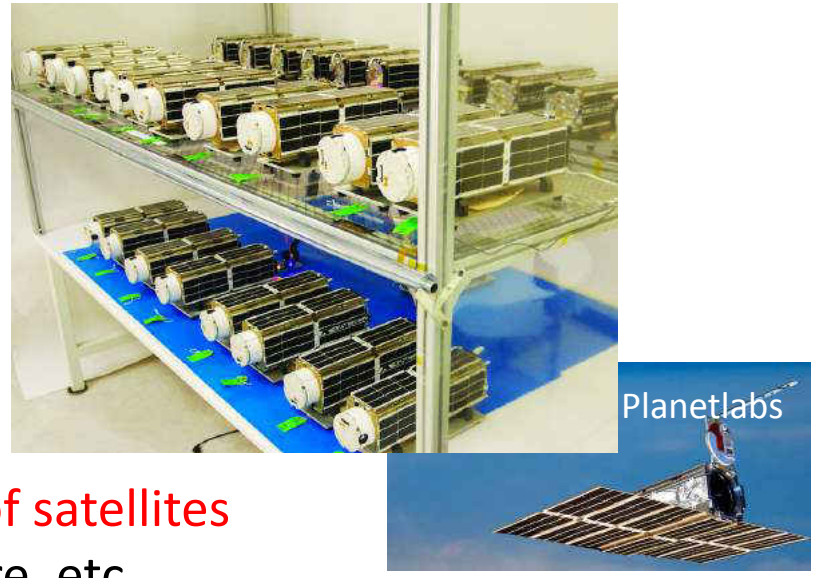
spectral imaging with several bands

Skybox Imaging

- constellation: 100kg x 20 satellites
- Google bought Skybox Imaging with 500 M USD and suggest to increase the number up to 100-200 or more??



(c) Skybox Imaging

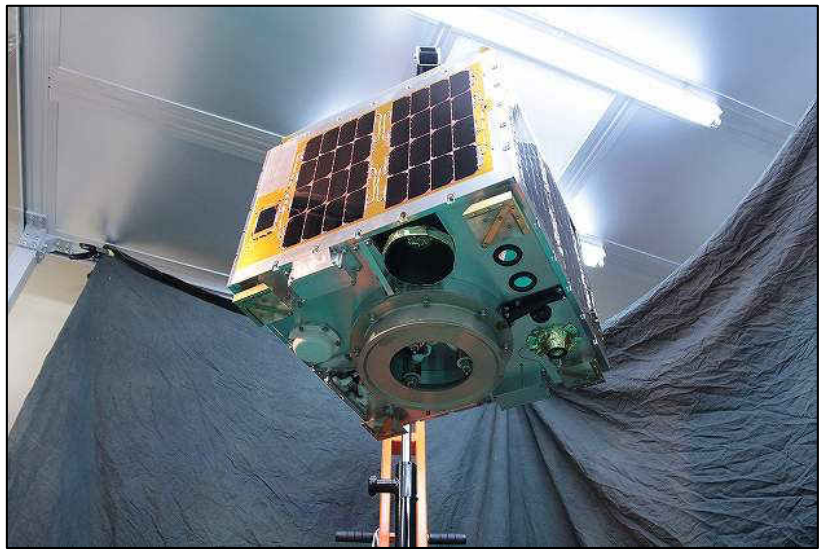


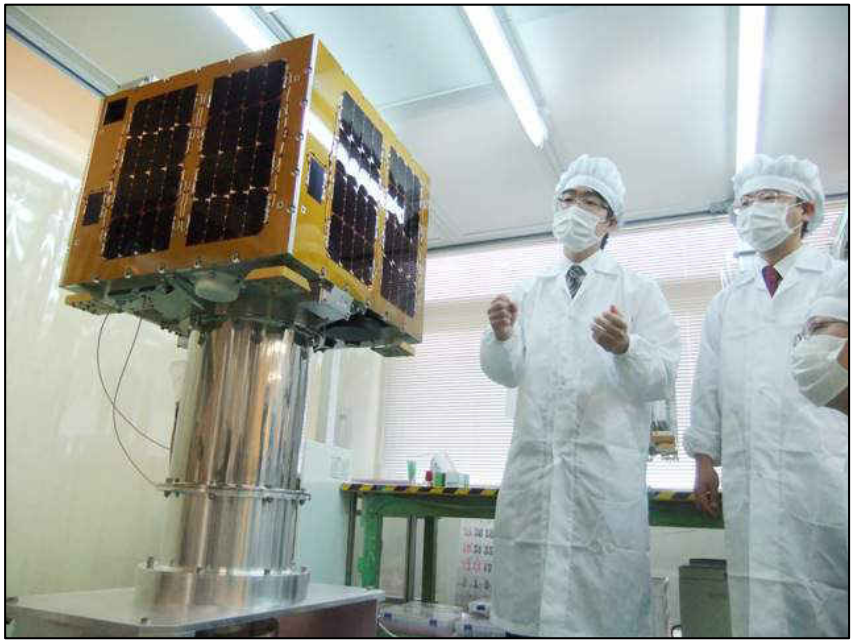
Planetlabs

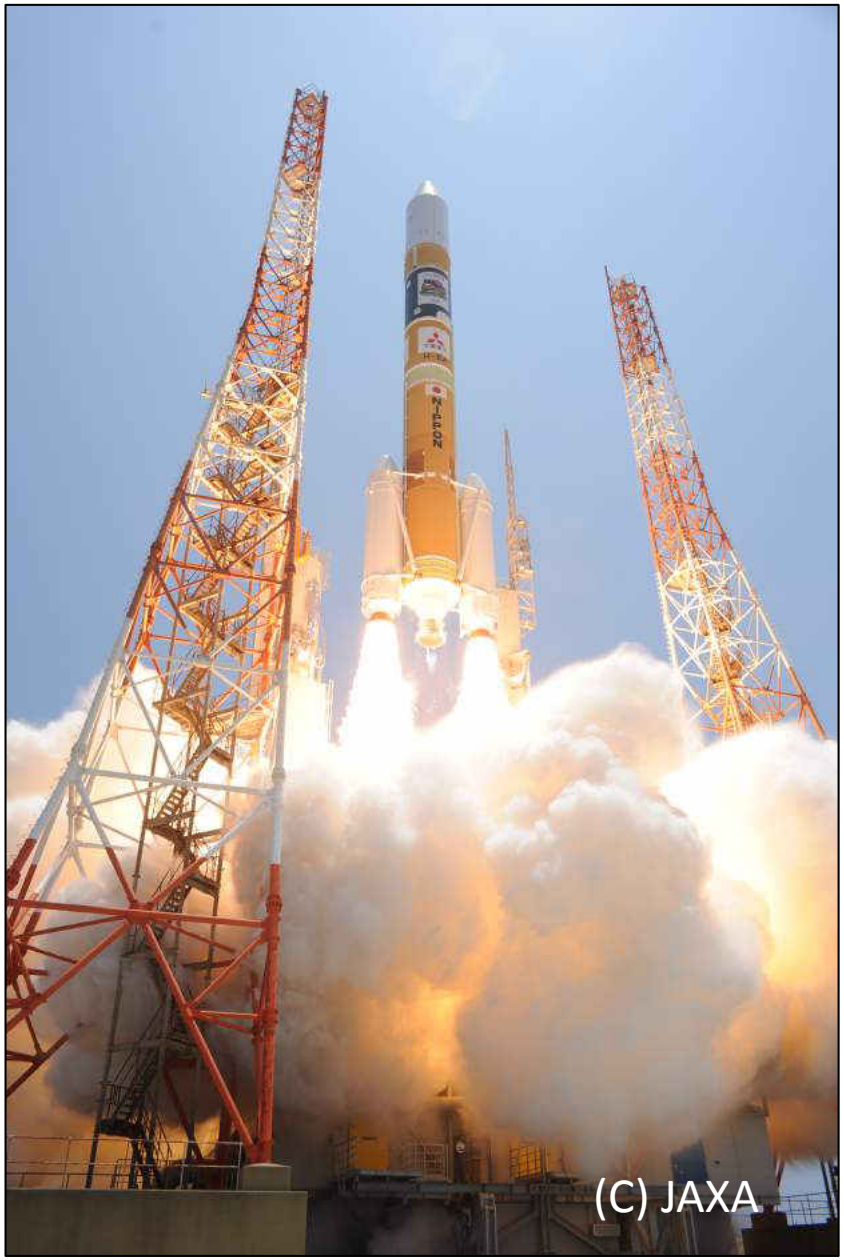
- 3U Cubesat constellation consisting of 100s of satellites
- multi-spectral camera dedicated to agriculture, etc.

and more...

RISING-2 satellite (launched in 2014)

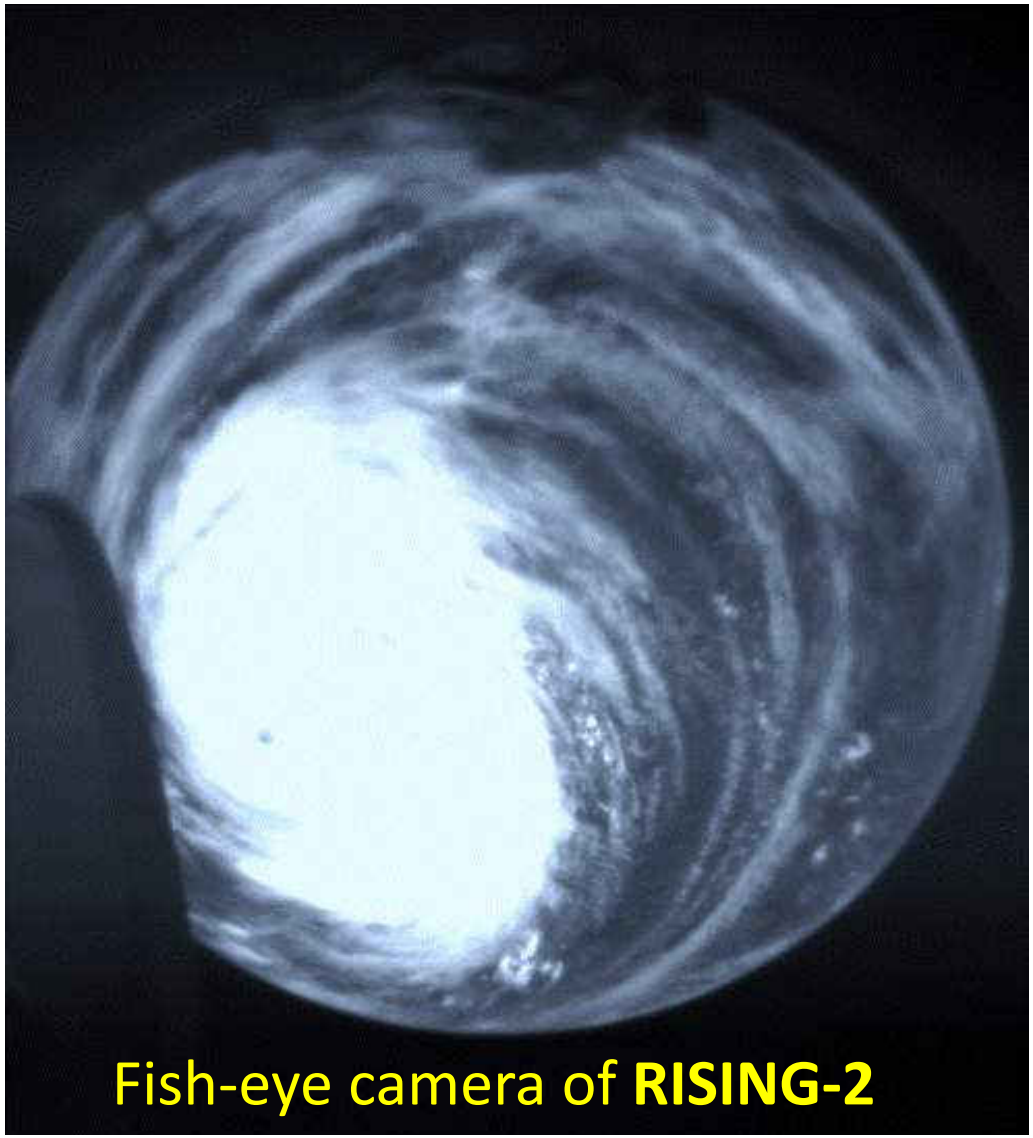


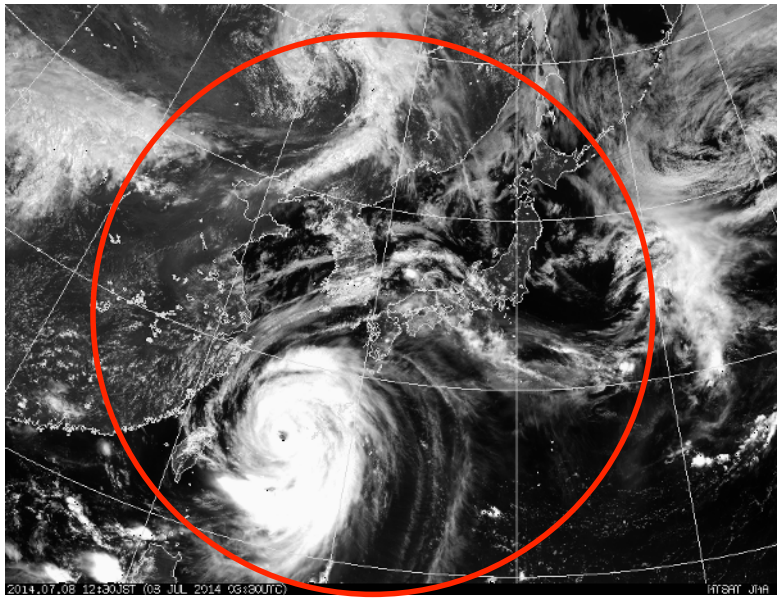




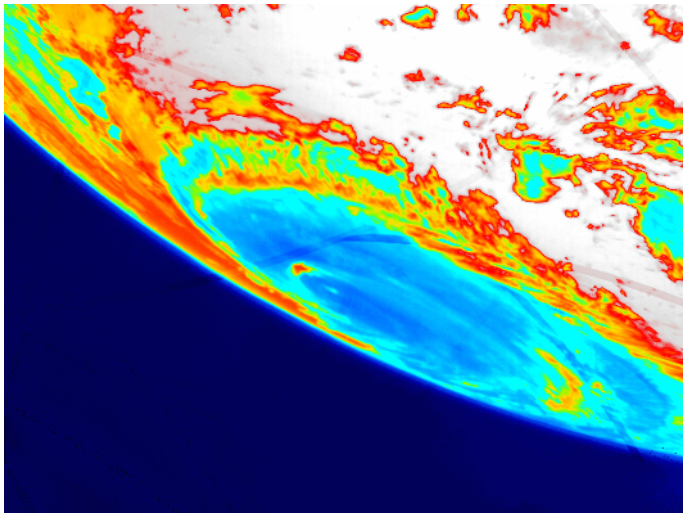
Launched as piggyback

Typhoon 2014-#8 Nogree





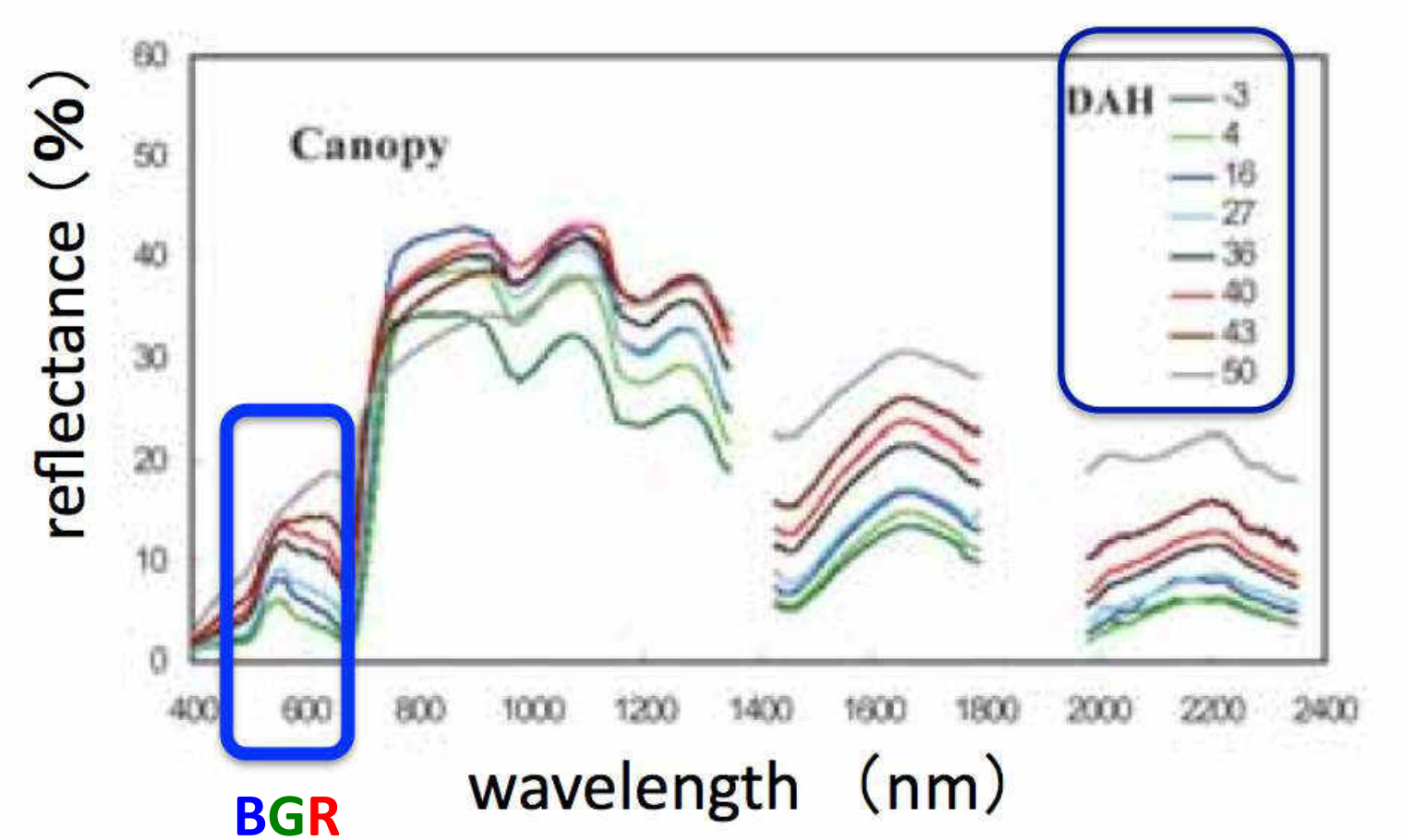
from geosynchronous orbit



Thermal Infrared Image
by **RISING-2**

Spectral measurements

Rice spectrum



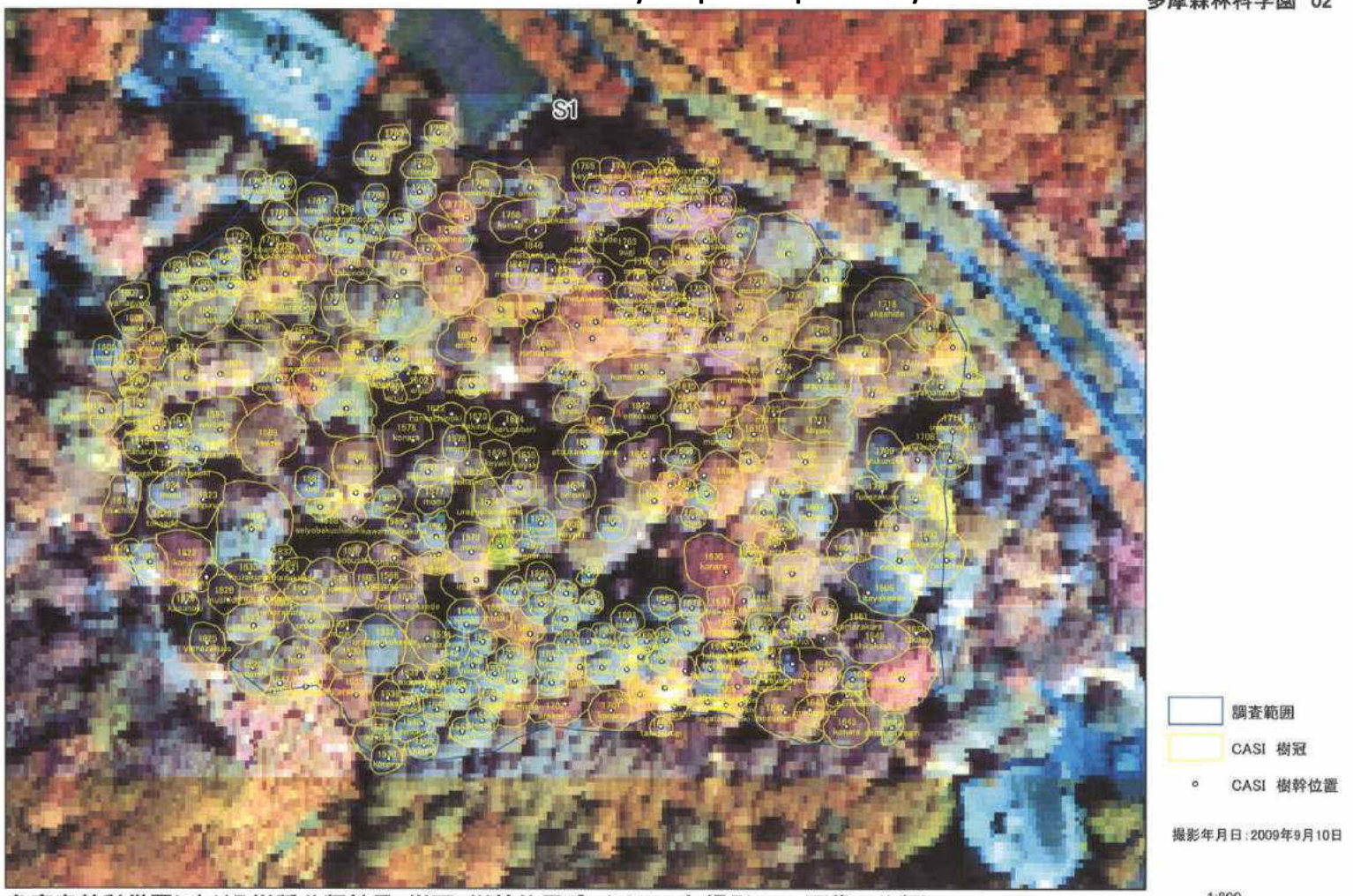
Seasonal change in reflectance of rice canopy during ripening period (DAH: days after heading) [Inoue et al., 2008]

Application of spectral imaging

Identification of tree species

Airplane

by Japan Space Systems



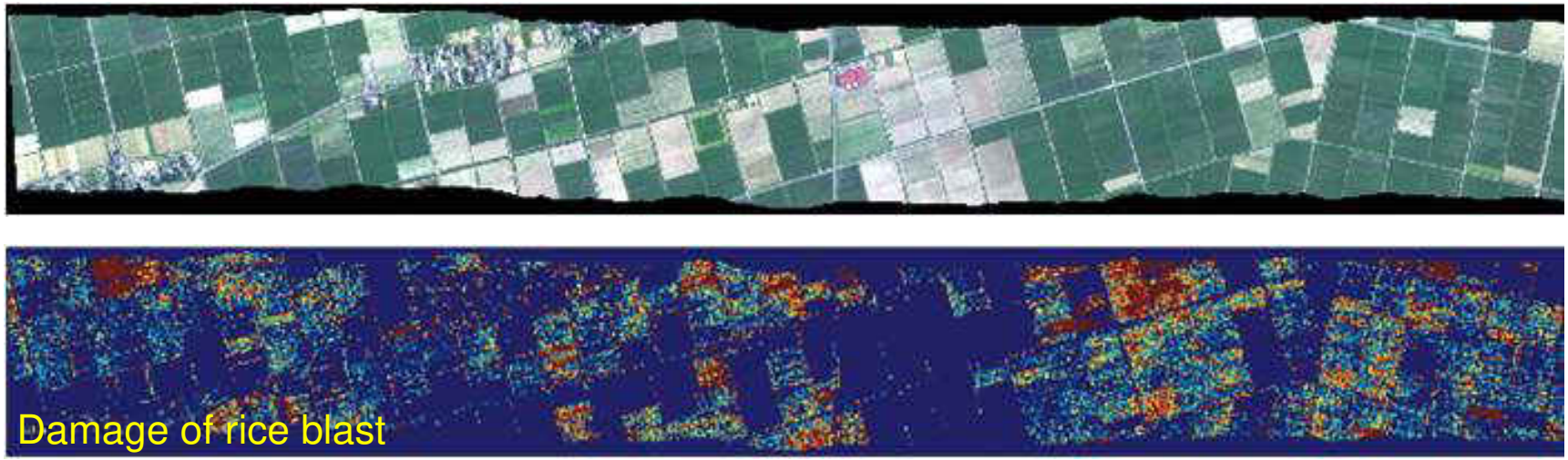
多摩森林科学園における樹種分類結果：樹冠・樹幹位置データ（2009年撮影CASI画像で分類）

150 species with 70% accuracy

Application of spectral imaging

Disease detection

by hyper-spectral sensor (not LCTF) on board airplane



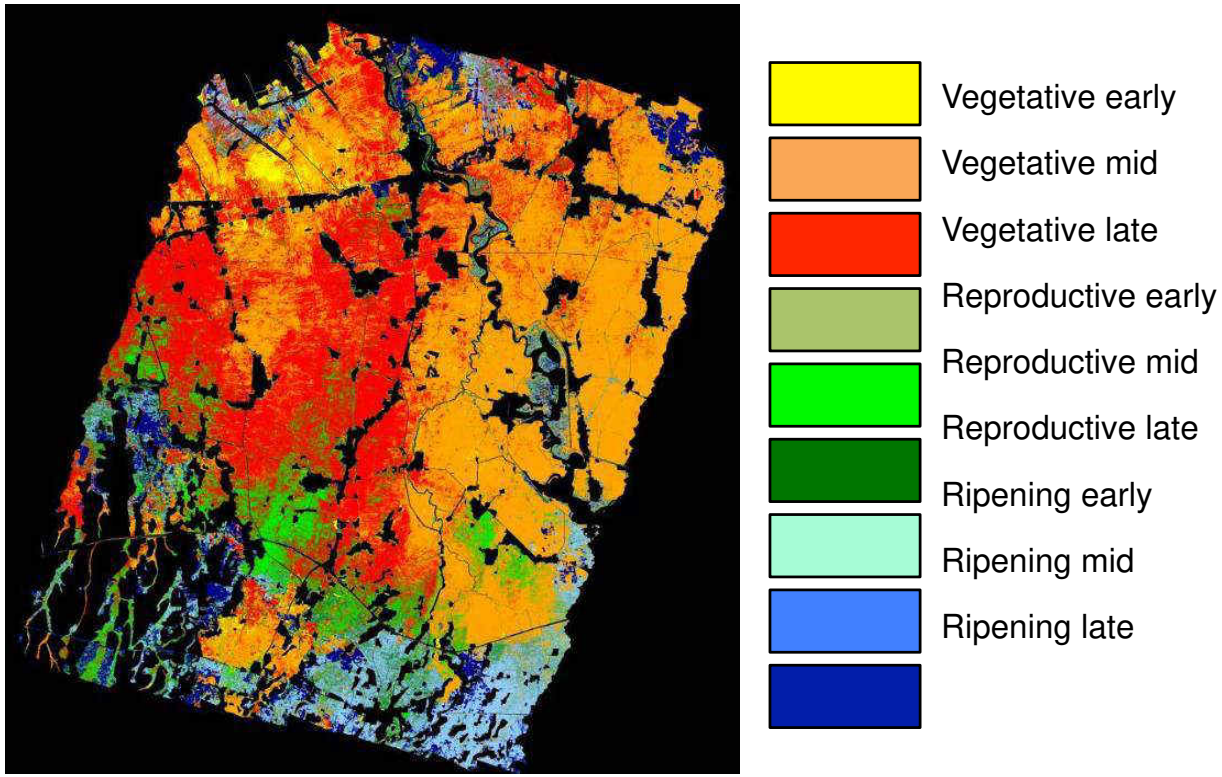
AISA (400～2500nm, 195 bands, 1.5×1.5 m), 2009/8/26, Yamagata, Japan

could detect disease before detection on the ground

Application of spectral imaging: growth stage

by hyper-spectral sensor (not LCTF) on board airplane

Rice growth stage (Indonesia)



HyMAP (440～2480nm, 126 bands, 5.0×5.0 m), 2008/7/1, Subang, Indonesia
by airplane

北海道大学
HOKKAIDO UNIVERSITY

But these works are carried out with large and heavy hyper-spectral sensor onboard manned airplane

example

図 CASI-3 の外観

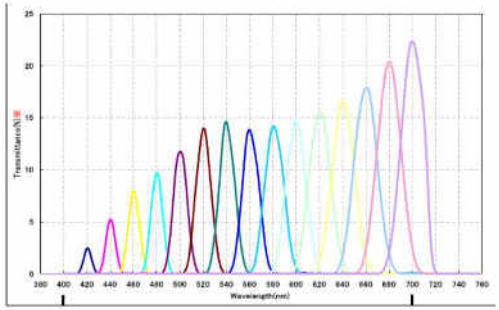
表 CASI-3 機器諸元

装置名	CASI-3 (Compact Airborne Spectrographic Imager)
製造元	Itres Inc. (CANADA)
空間方向ピクセル数	1456 (Spatial Mode)/1301 (Spectral Mode)
波長方向ピクセル数	288
走査角	39.09° (Spatial Mode)/35.13° (Spectral Mode)
光学分解能	約 0.47mrad
量子化ビット数	14bit
データ収録媒体	HDD
輝度補正	別途キャリブレーションテーブルによる
幾何補正	GPS/IMU(Applanix 社製 POS/AV)による

Liquid Crystal Tunable Filter camera

Airborne Multicolor Imager (AMI)

Transmittance (VIS-type LCTF)



400 700 nm

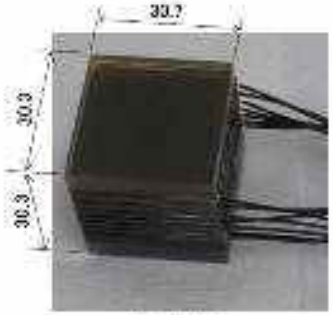
AC adapter → AC power supply

Windows-based PC

USB cable

Multispectral Camera
- Wide FOV lens
- High-sensitive CCD
- Liquid Crystal Tunable Filter (LCTF) for Visible
- 190 x 100 x 100 mm
- 1.3 kg

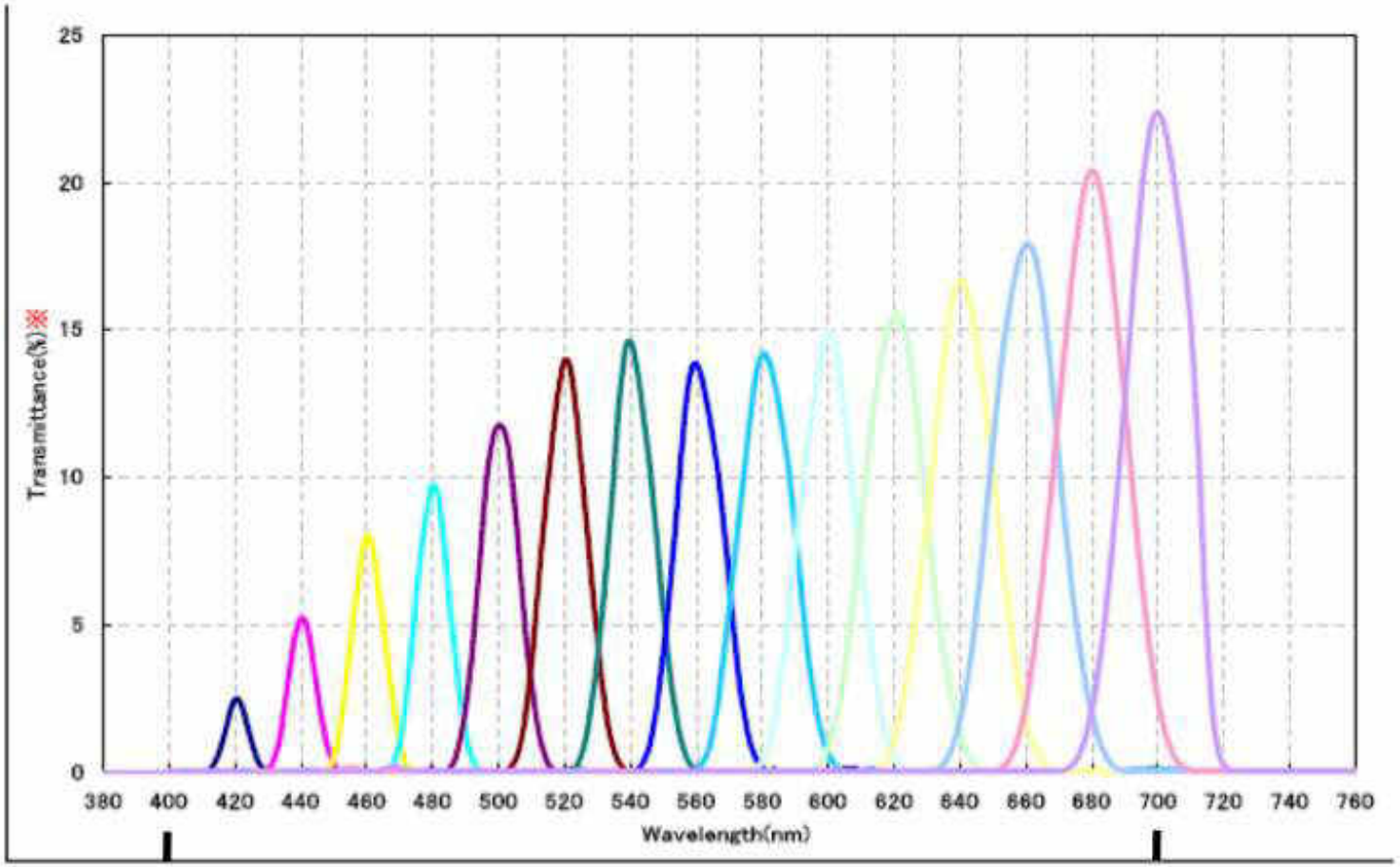
Camera controller
- 100-240 V AC input
- USB 2.0 interface
- 300 x 200 x 60 mm
- 2.0 kg



LCTF

Specifications	
Wavelength range	420 - 700 nm
Band width (FWHM)	8 - 25 nm
Response time	< 0.3 sec
Frame rate	> 1 frame /sec
Number of pixels	659 x 494
Field of view	92 degree

Transmittance (VIS-type LCTF)

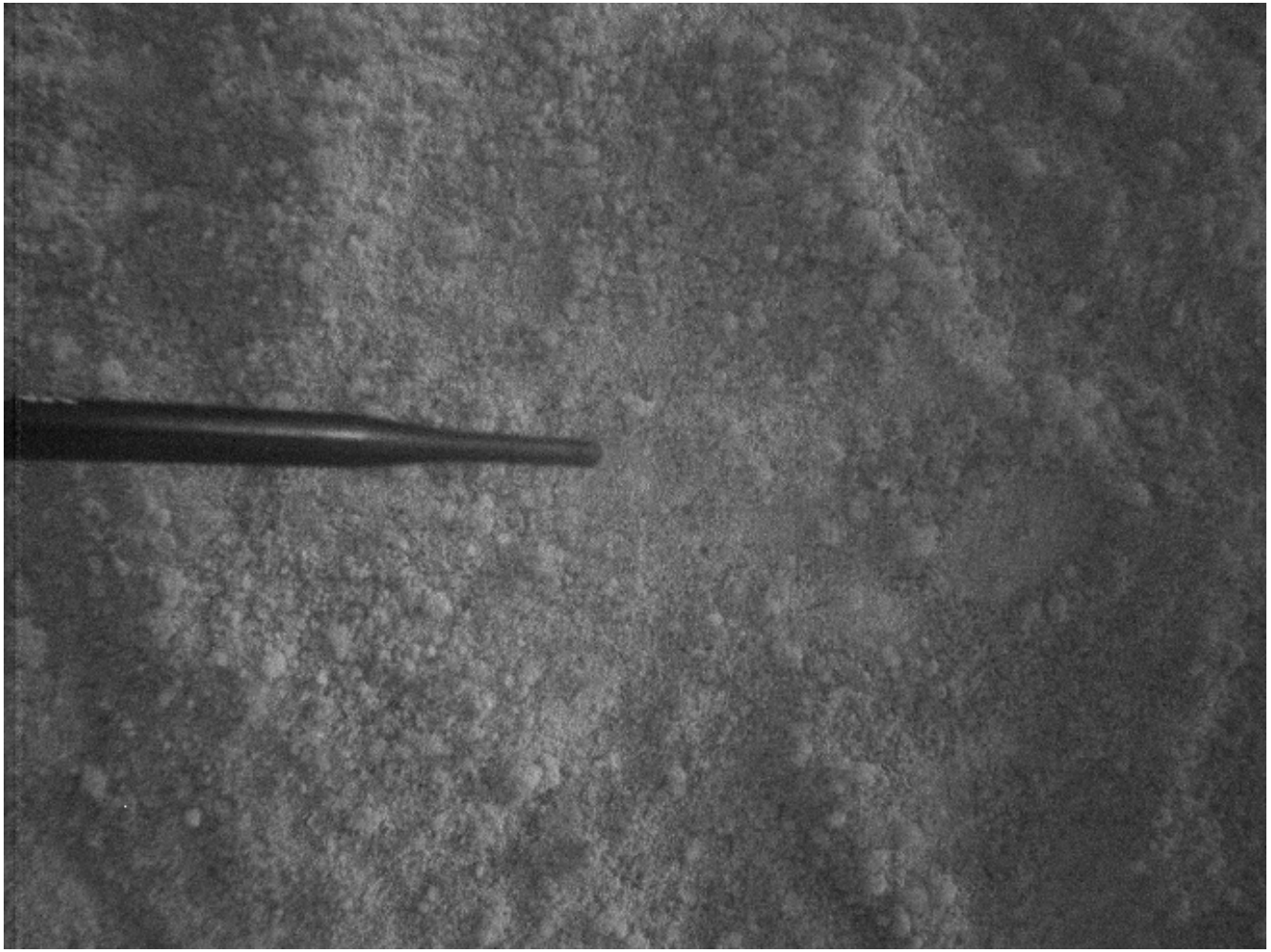


Aircraft (UAV) campaign with AMI in Java
（2012/10/29-31）

UAV developed and owned by **BPPT**

10/31 ~18:40

forest in the target area



flight direction of UAV ~ 30 m/s

2.5 m/pixel

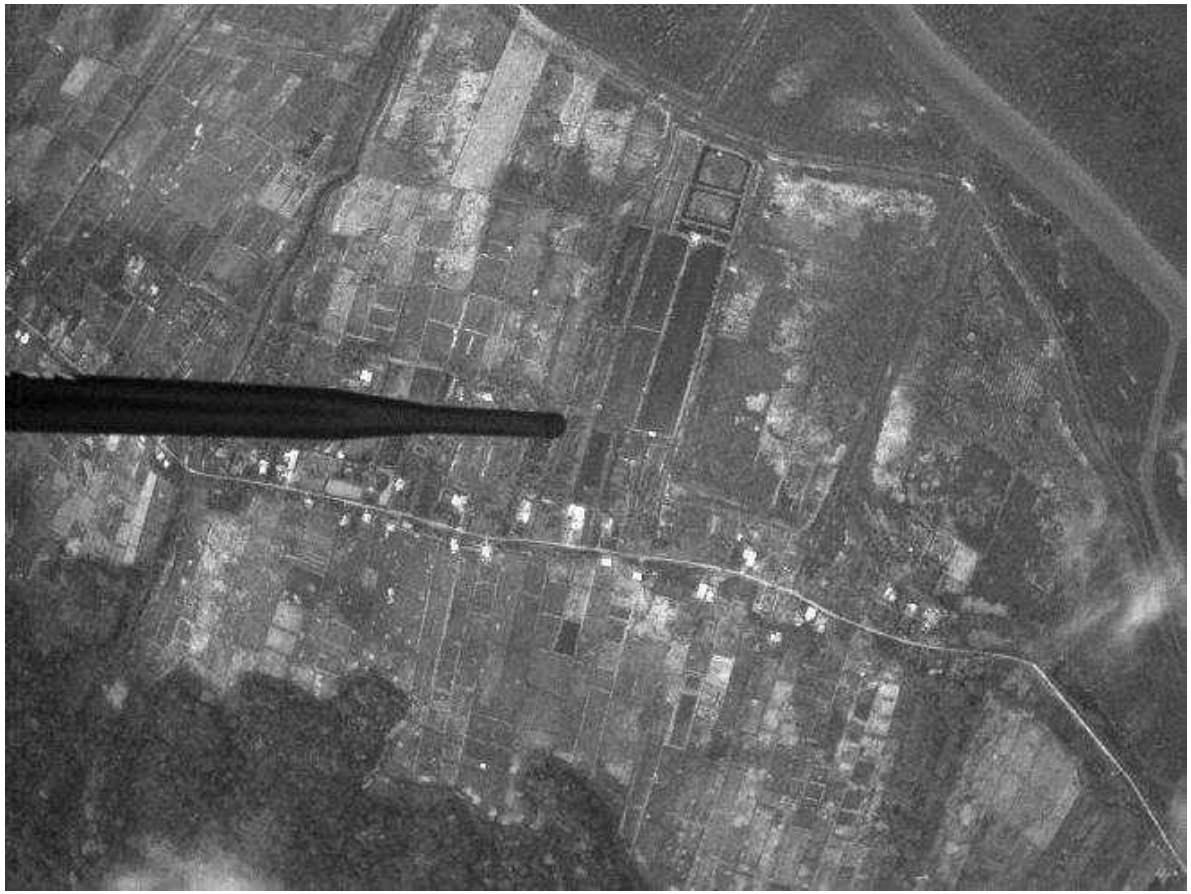
~1.2 km

@420 nm

18h:40m:08s:918ms

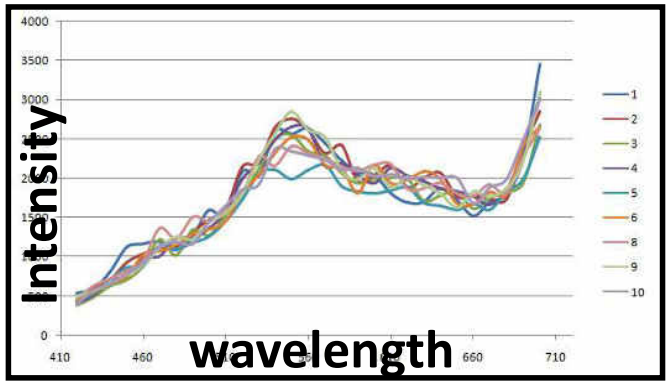
~1.6 km

changing colors in 420-700 nm
at 10 nm step (29 bands)



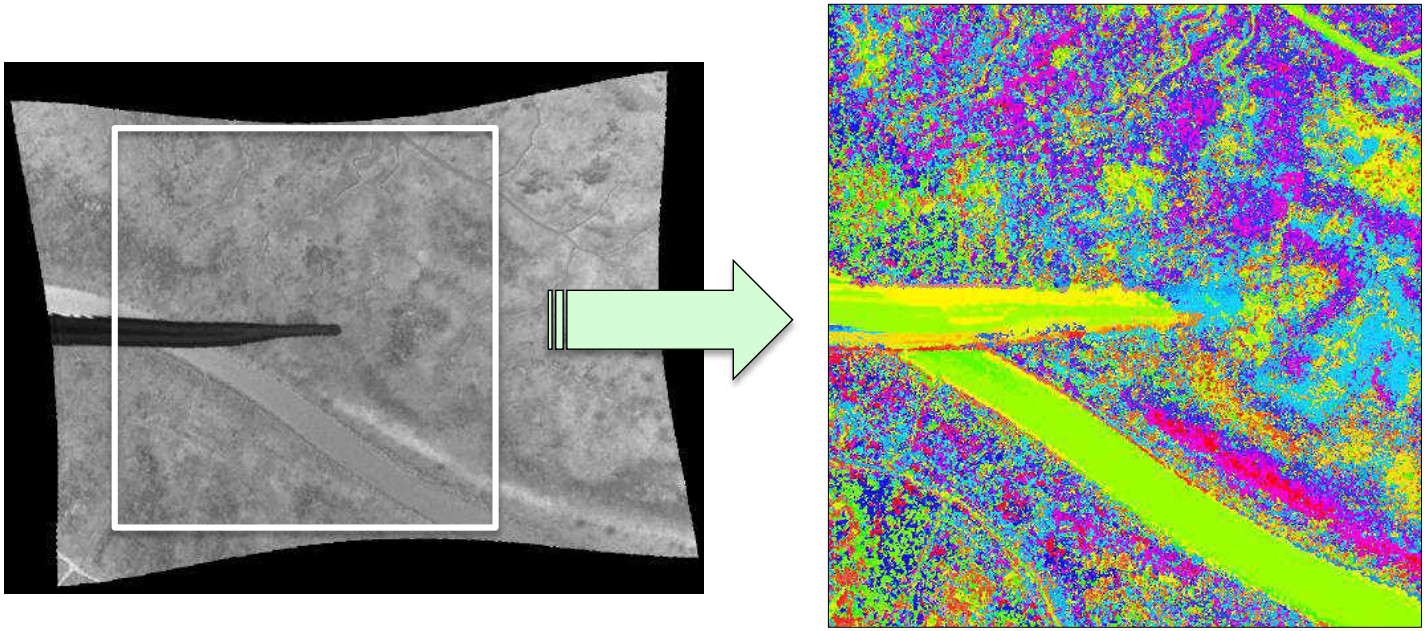
effects of vibration and unstable attitude are very small

LCTF camera is the only way to realize both high spatial resolution and detail spectral measurement with micro-satellite or UAV.



from 30 wavelengths

900 m



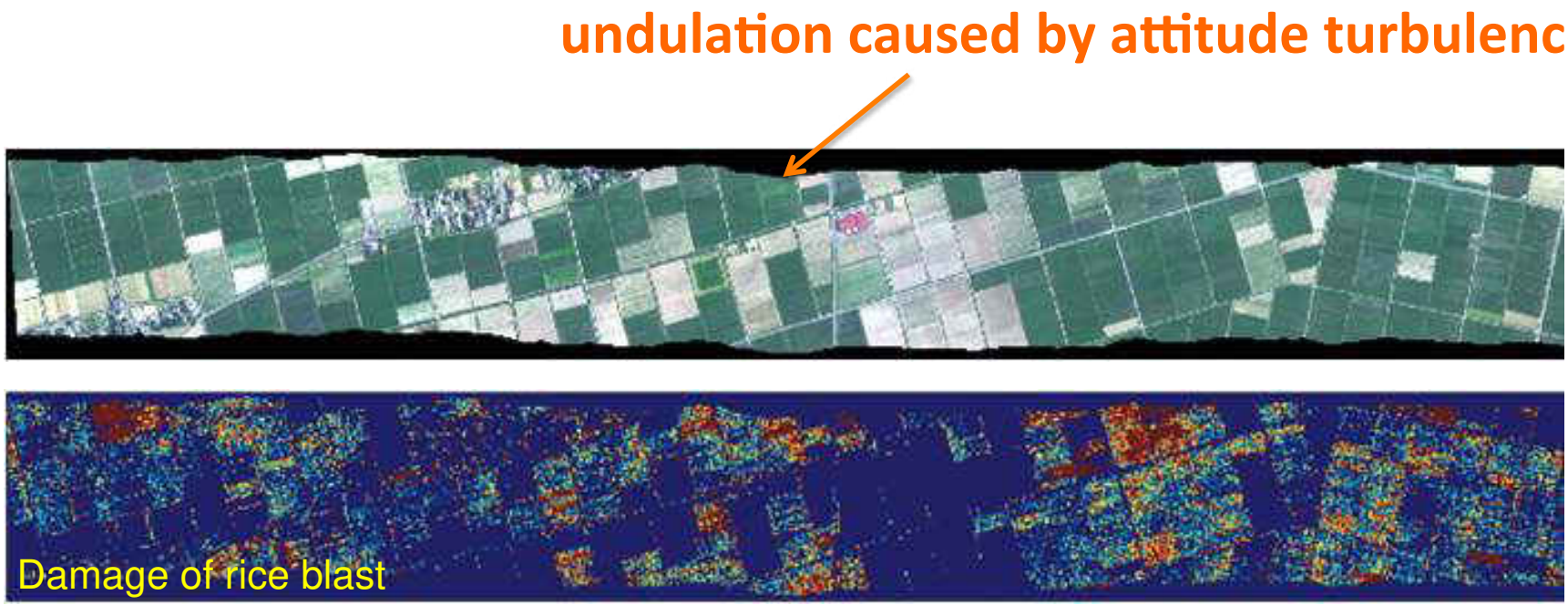
classification of species or monitoring condition for each tree...

Only our liquid crystal technology satisfies
both high spatial resolution and super spectral measurement

3-kg (now 1.5kg) super-multicolor imager
with liquid crystal tunable filter (LCTF)

the world's first and still only LCTF camera for drone/satellite use.

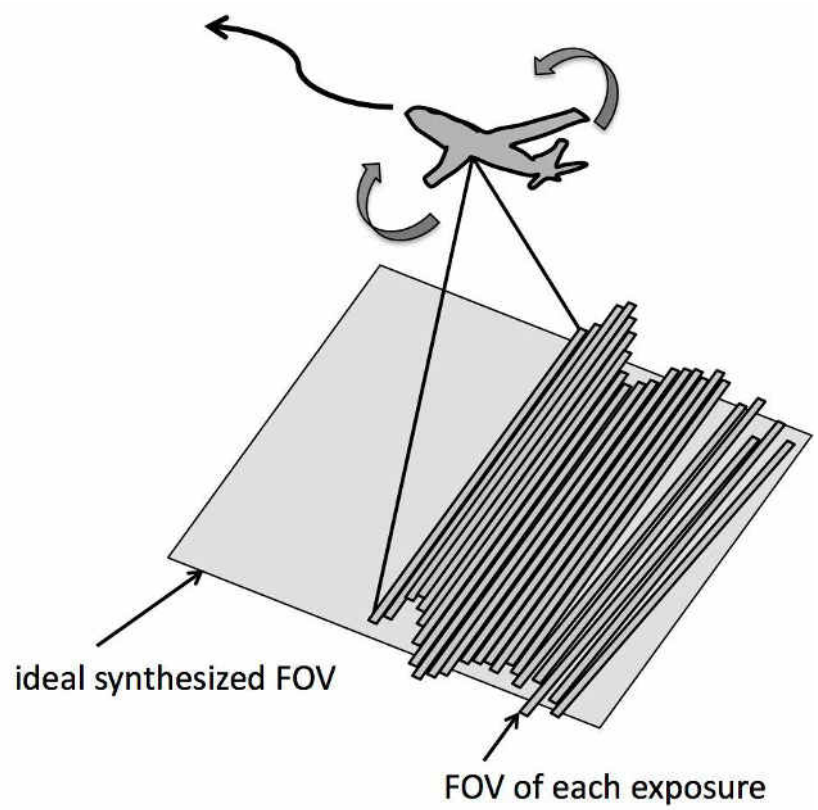
Problem of hyper spectral sensor --- unstable attitude



AISA (400～2500nm, 195 bands, 1.5×1.5 m), 2009/8/26, Yamagata, Japan

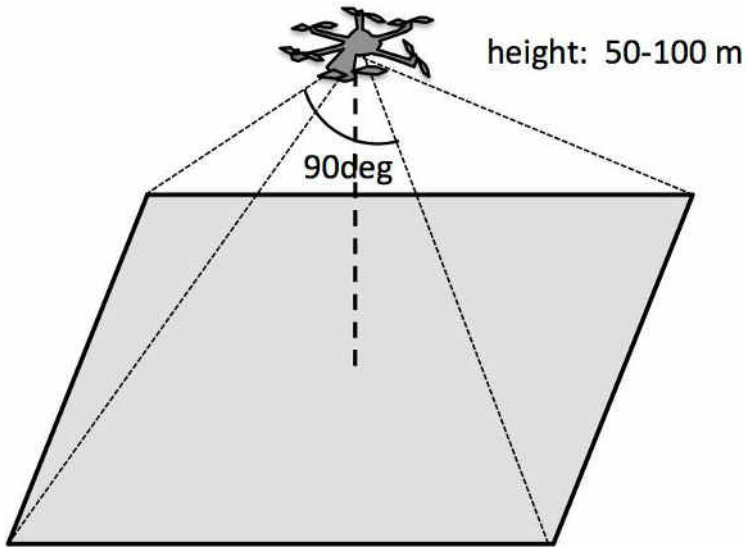
Combination with Drone and ground measurements

conventional sensor



Conventional hyper-spectral imaging using fixed wing aircraft and pushbroom type sensor

new LCTF camera

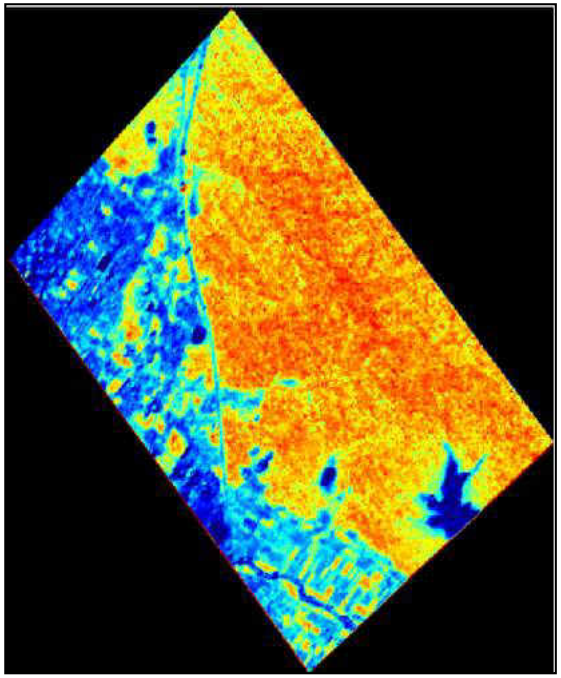


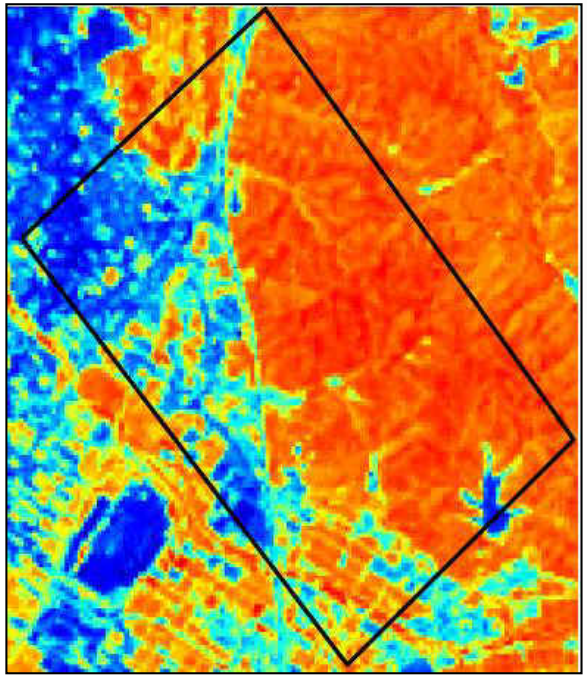
Our super multicolor imaging with LCTF camera and multicopter

resolution: 10cm order

Spectral measurement with satellite

Vegetation Index: indicator of species or activity

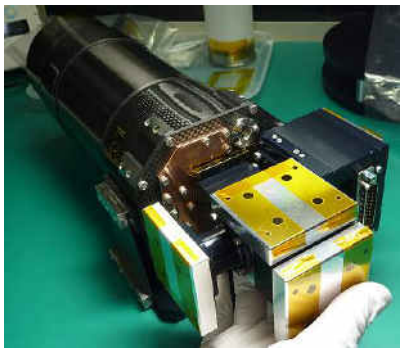




RISING-2 (2014/9/14)

LANDSAT-8 (2013/8/14)

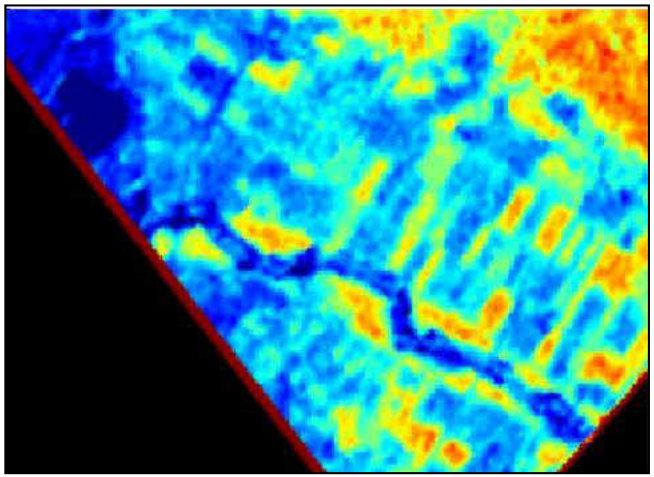
Hikone city



Liquid Crystal Tunable Filter (LCTF) telescope

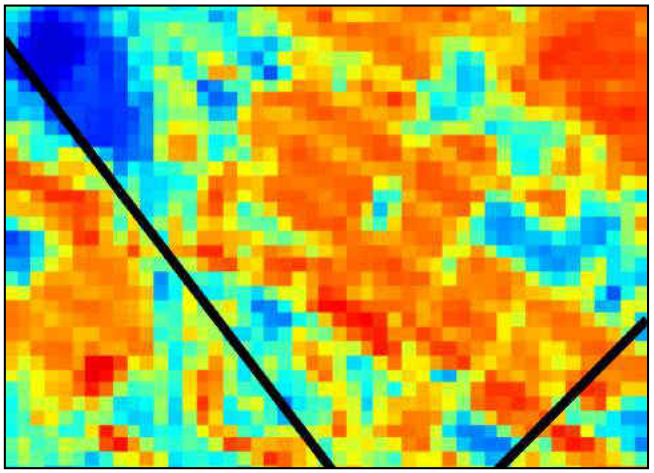
- range: 650 - 1050nm
- 1-nm step selection (400 bands)
- switching time: order of 10s-msec

RISING-2: the world's best resolution with > 100 bands



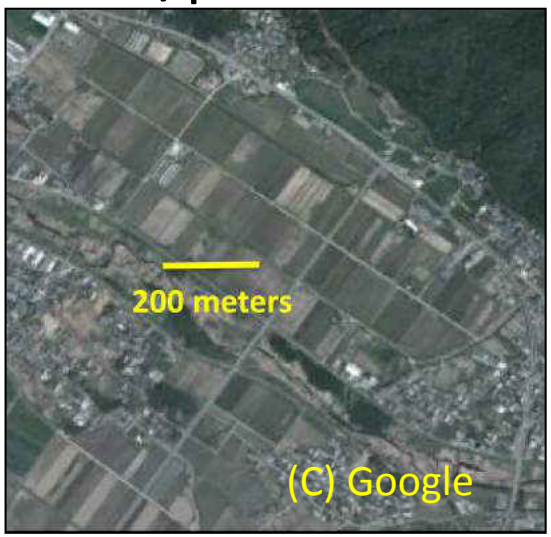
RISING-2

5 m/pixel



LANDSAT-8

30 m/pixel

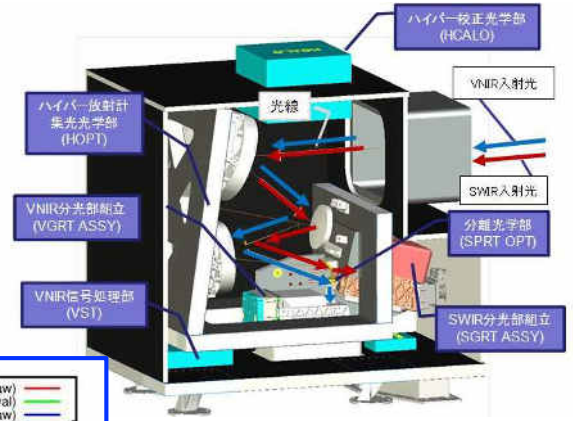


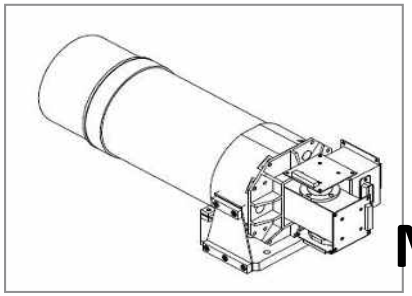
HISUI (Japan), enMAP (Germany)

Hyperspectral sensor ⟺ LCTF camera

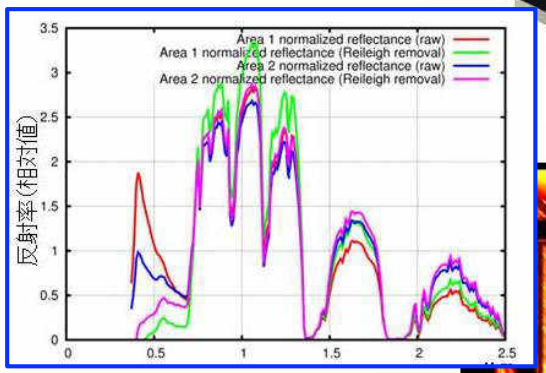
Simultaneous spectrum, **30 m GSD, 1/ 140-day** Selectable bands, 5m GSD, high freq.

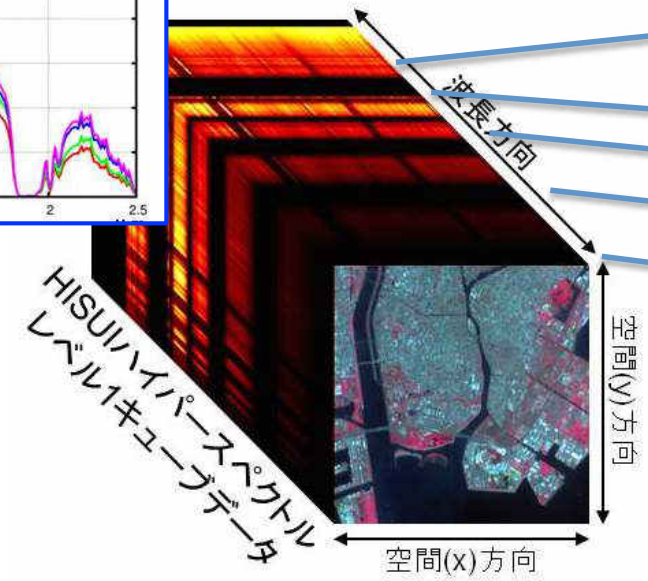
HISUI on ISS

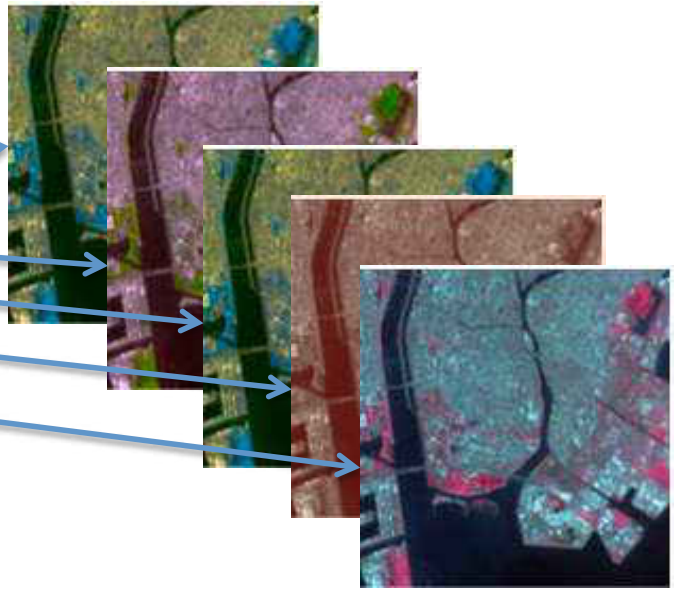




Micro-satellite



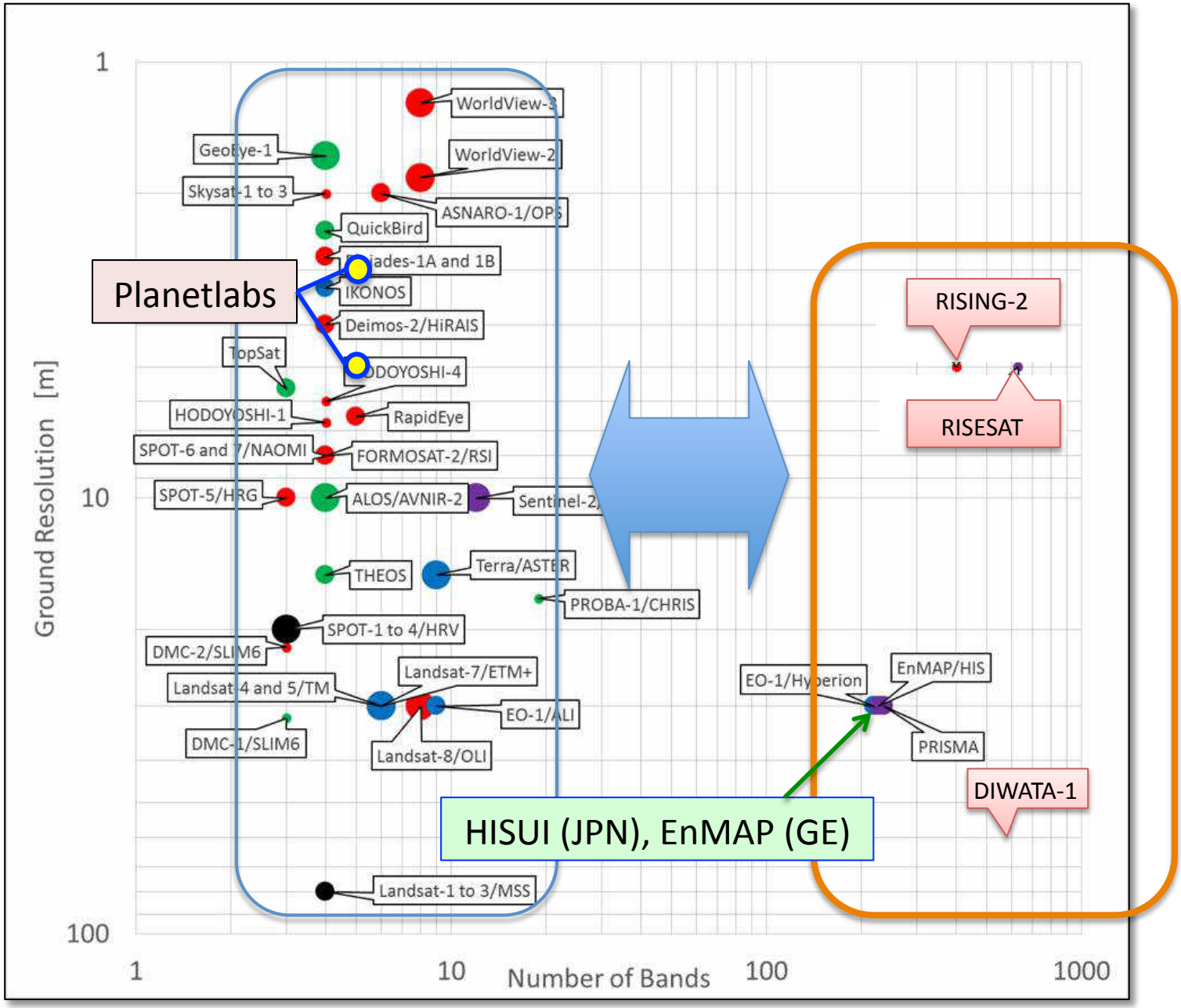




185 wavelengths, 30 m/pixel

< 10 wavelengths, 5m/pixel

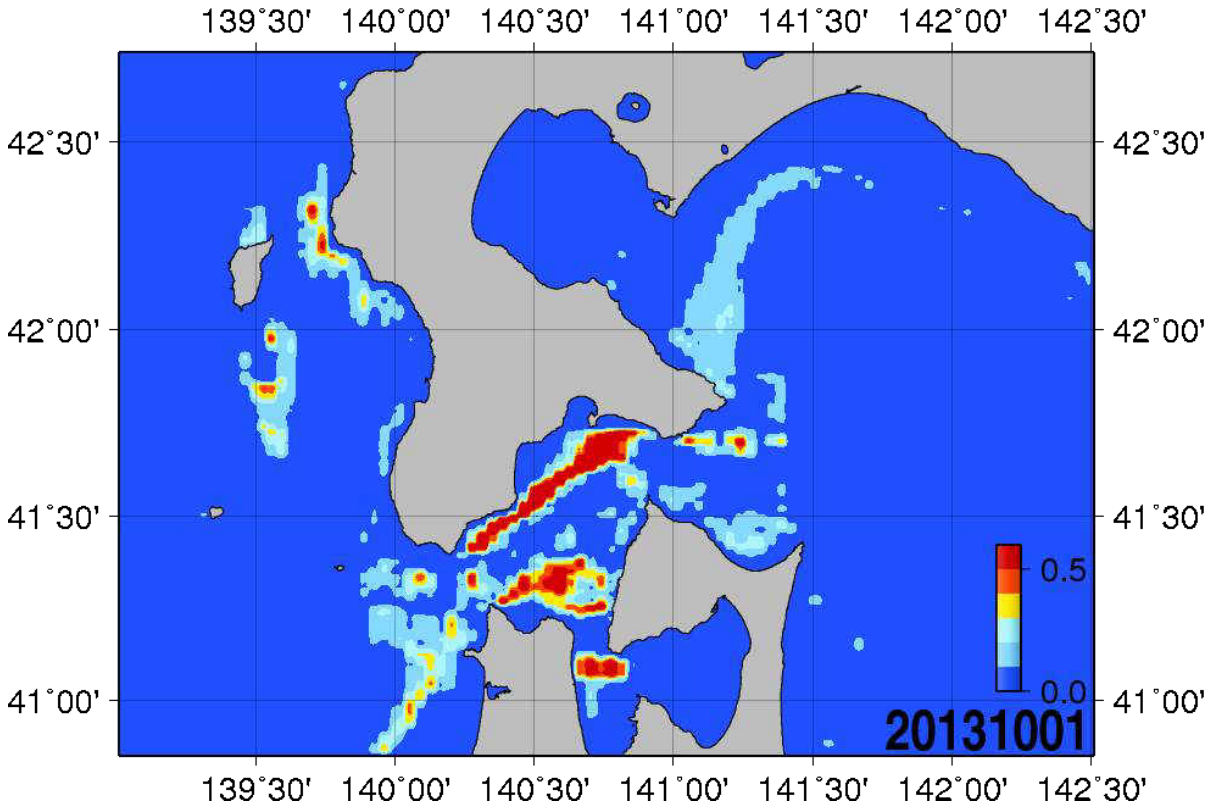
北海道大学
HOKKAIDO UNIVERSITY



Application of spectral imaging

Prediction of fishing area based on existing satellite data

Based on satellite data, such as, distribution of chlorophyll, sea surface temperature, the best fishing place are estimated for each species.

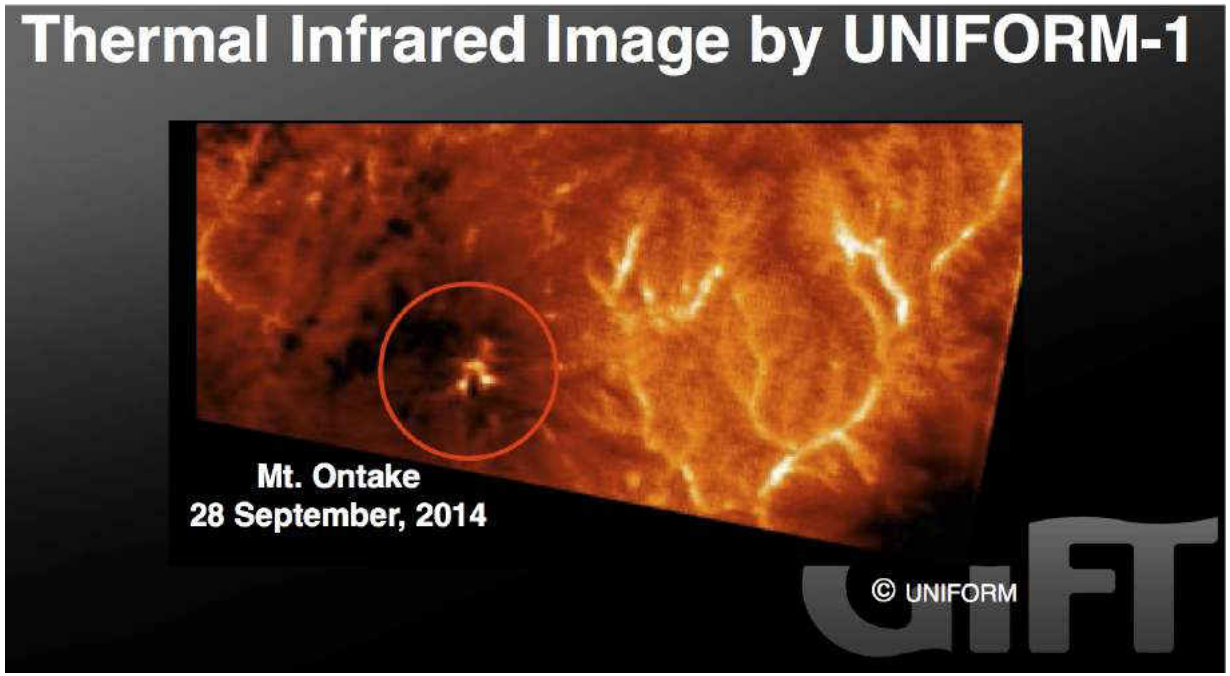


Prof. Saito @ Hokkaido University

70% accuracy, saving fuel by 20-30%

UNIFORM-1 satellite developed and operated
by University Union in Japan
Launched in May, 2014

dedicated to forest fire detection (+ monitoring of volcano)



Background of our team

Tohoku University (satellite bus)

top level experiences and heritages in making satellite bus

taking over space company's experiences for > 10 satellites

Hokkaido University (payload and applications)

the world's best optical sensor technology for micro-satellite

one of the largest user communities in Japan

Representative heritages

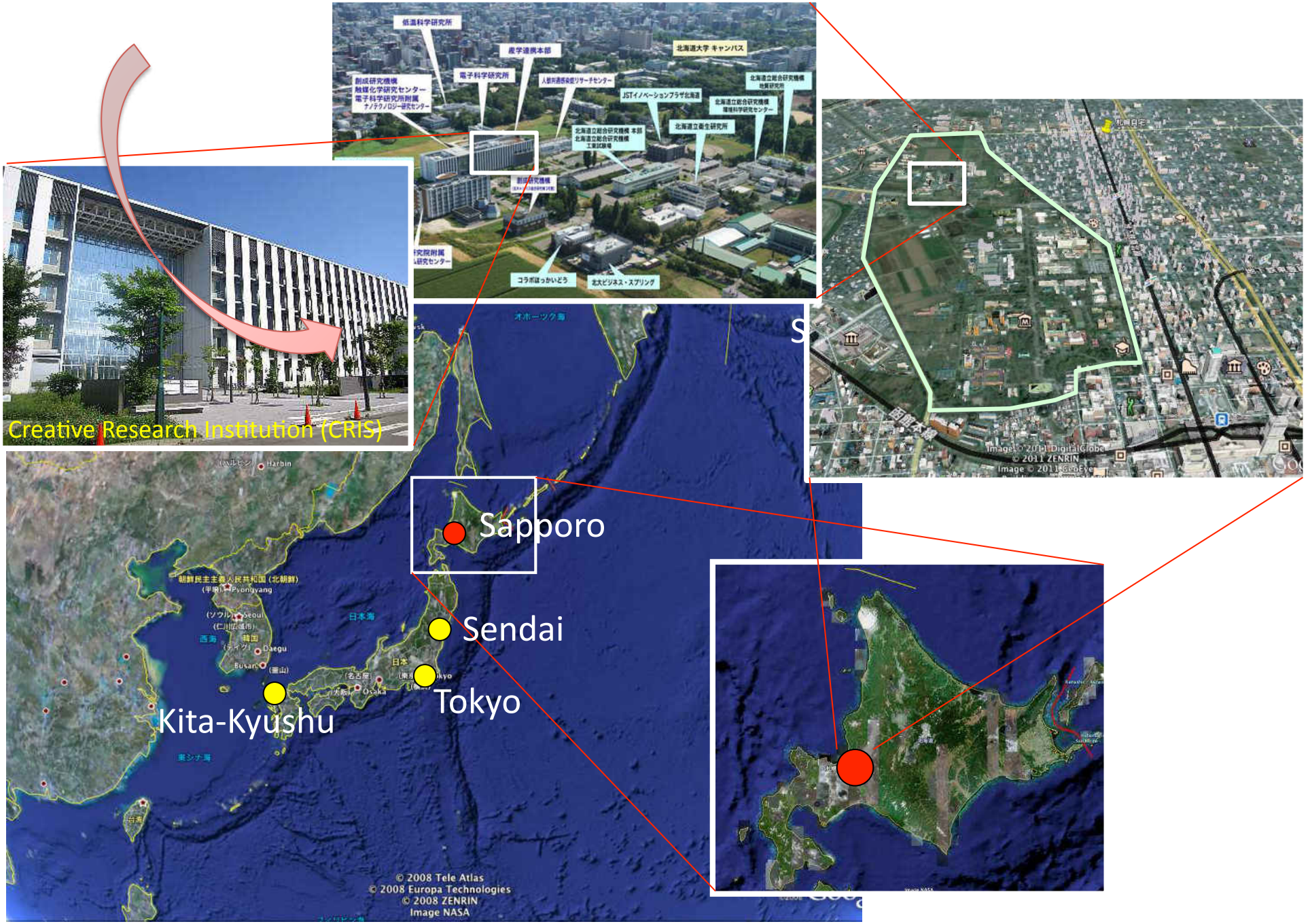
micro-satellites

SPRITES-SAT (2009), RISING-2(2014), UNIFORM-1 (2014),
DIWATA-1 (2016), RISESAT (2018), MicroDragon (2018)

nano-satellite and international space station

RAIKO (2U CubeSat), JEM/GLIMS (sensor onboard ISS)

Space Mission Center (SMC) of H.U.



Facilities for development and testing in microsatellite development lab.

One stop site for micro-satellite development

■ Thermal chamber

■ Thermal vacuum chamber

■ Class 100 clean booth and darkroom

■ Vibration test facility,
■ Shock test facility,
■ Radio wave darkroom are available at Hokkaido Research Organization


Program Title: Development of Philippine Scientific Earth Observation Micro- Satellite (PHL-MICROSAT)

Philippine project: DIWATA-1 and -2

meeting with secretary of DOST(2013)

Philippine delegates led by undersecretary（2014）

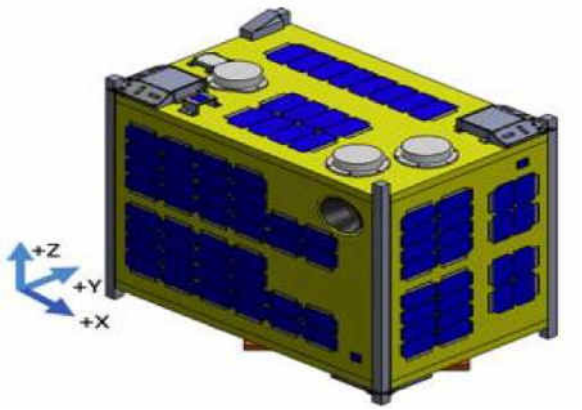
- meeting with secretary and undersecretary of DOST (2013 Jan) in Manila
- Half year later DOST official contacted Hokkaido University
  selected Hokkaido/Tohoku instead of NASA
- 3 year project started in 2016 Jan, launching 2 micro-satellites, developed by Philippine students
- the first satellite will be released fro ISS and was handed over to JAXA
- 7 master course students (+2) are studying in Hokkaido/Tohoku Universities
- 10 M USD for two satellite and capacity-building are covered by DOST, Philippines.

cameras on board DIWATA-1

	HPT	SMI with LCTF	MFC	WFC
Field of View	1.9 x 1.4 km	52 x 39 km	121.9 x 91.4 km	180° x 134°
Spatial Resolution	3 m	60 m	185 m	7 km
Spectral Range	NIR/R/G/B	2 LCTF: 433 - 740 nm 730 - 1020 nm	Colored	Panchromatic
Spectral Resolution		FWHM: 10 - 30 nm 1 nm step		

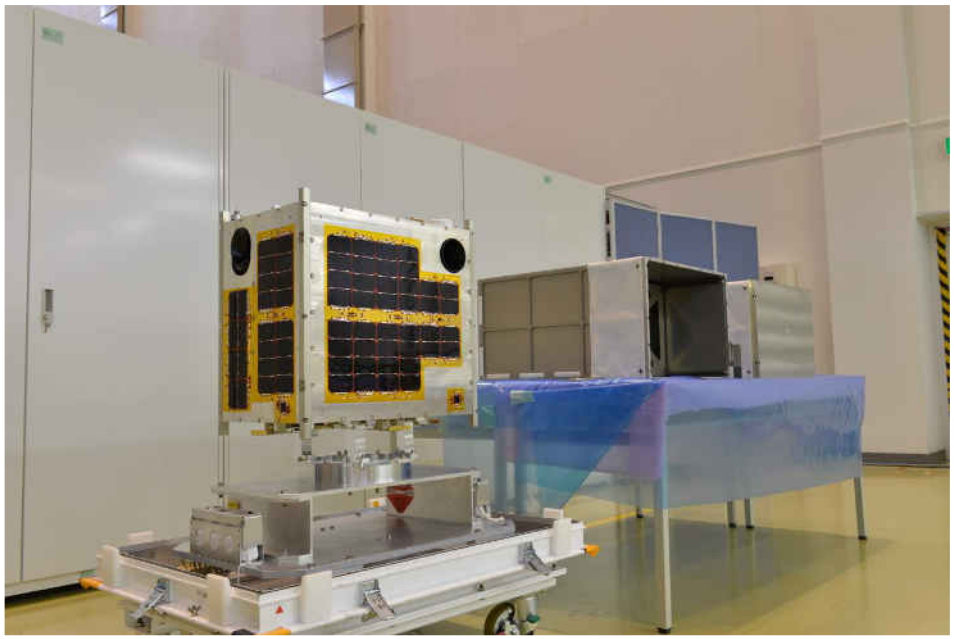
In about 3 years two satellite are developed and launched

Activities	I. Prelimary Design			II. Basic Design					III. Eval. of EM System			IV. Fabrication of FM			V. Accept. Test			
	2014			2015												2016		
	9	10	11	12	1	2	3	4	5	6	7	8	9	10	11	12	1	2	3
Prelimary Design Document																			
Consideration details																			
EM component fabrication																			
Test for EM component																			
Electrical test for EM system																			
EM structure design																			
EM structure fabrication																			
STM vibration test and modify																			
EM construction																			
EM thermal vacuum test																			
EM vibration test																			
Evaluation of EM design																			
FM fabrication																			
FM construction																			
Electrical test for FM system																			
FM thermal vacuum test																			
FM vibration test																			
Delivery																			

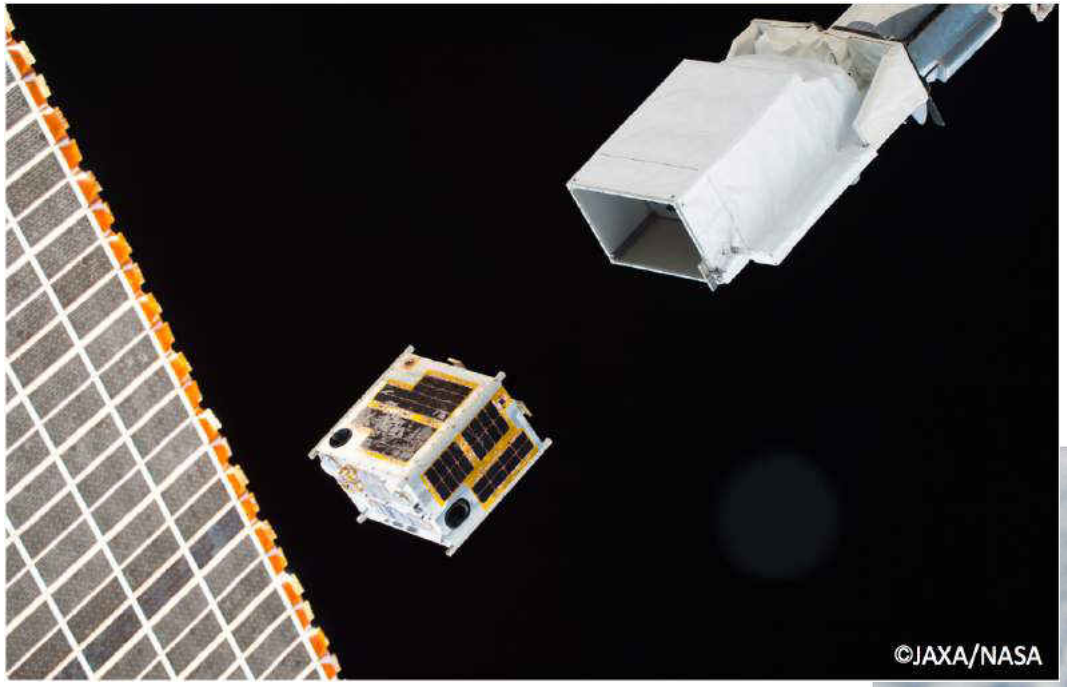


Kick-off Meeting
Mission Difinition Review
Preliminary Design Review
Mid-term Review
Critical Design Review
Flight Readiness Review

50kg-class Microsat Ground Test Model (EM) + Flight Model (FM)		1st year				2nd year				3rd year			
		1	2	3	4	1	2	3	4	1	2	3	4
Mission Analysis													
Bus-System Design													
Payload Design													
EM	EM Structure Manufacturing												
	EM Payload Manufacturing												
	Structure Analysys (Vib. Test)												
	EM Components Manufacture												
	(C&DH, Power, Comm., ADCS)												
	EM Assembling												
	EM Environment Tests												
Onboard Software Development													
Software Simulation													
Design Feedback													
FM	FM Components Manufacturing												
	(Structure, C&DH, Power, Comm., ADCS, Payload)												
	FM Assembling												
	FM Environment Tests												
	(Vibration and Shock Tests)												
	(Thermal Vacuum Test)												
	Final Integration and Operation Tests												



Deployment of DIWATA-1 from International Space Station



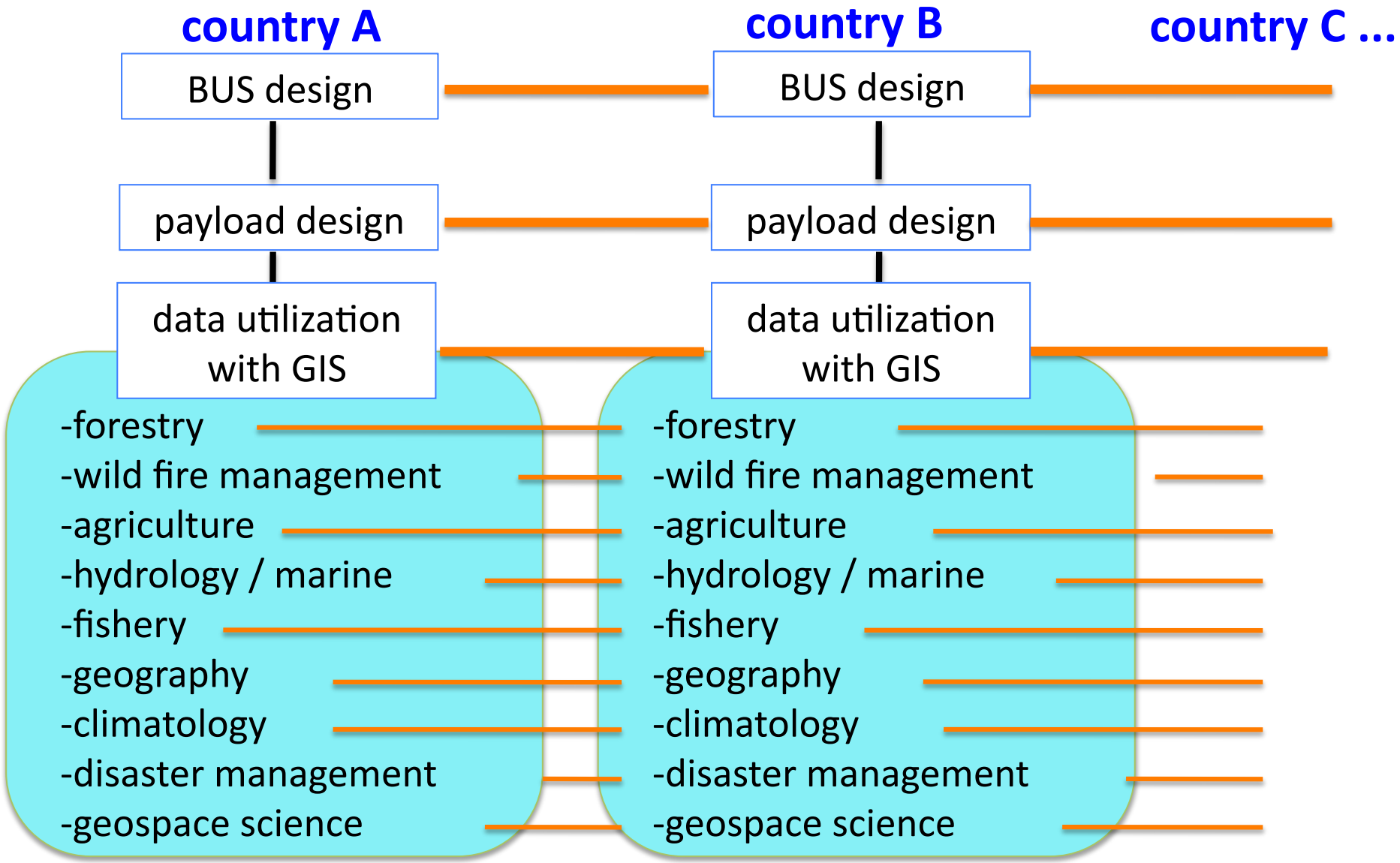
Asian Micro-satellite Consortium

to maximize the efficiency of space use, sharing data,
toward the **super-constellation** realizing real-time monitoring

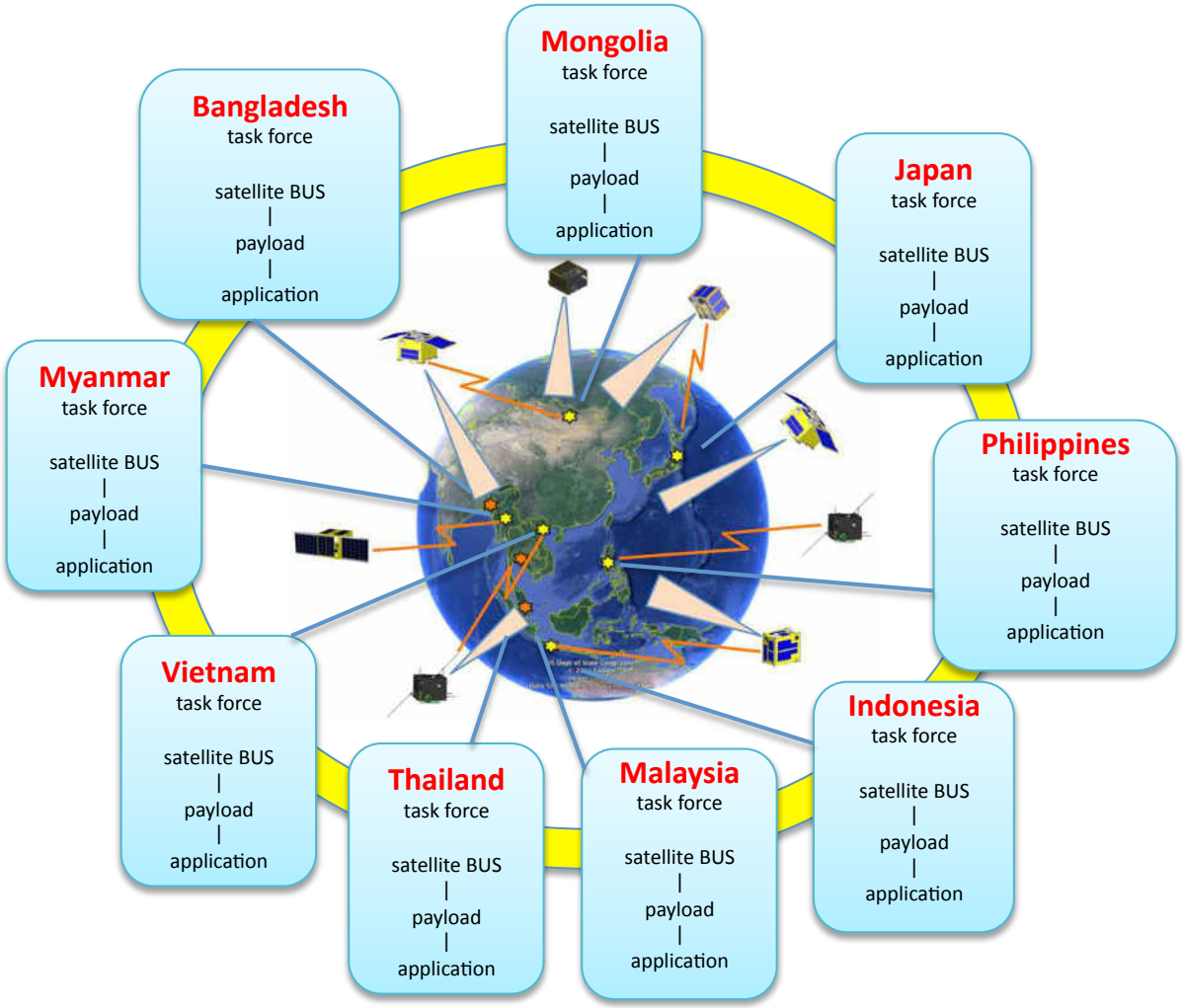
- sharing data, technology, and application
- standardizing sensor and operation system
- establishing ground validation

- involving 9 countries in Asia
- under signing by representatives of 11 institutes

Asian Micro-satellite Consortium



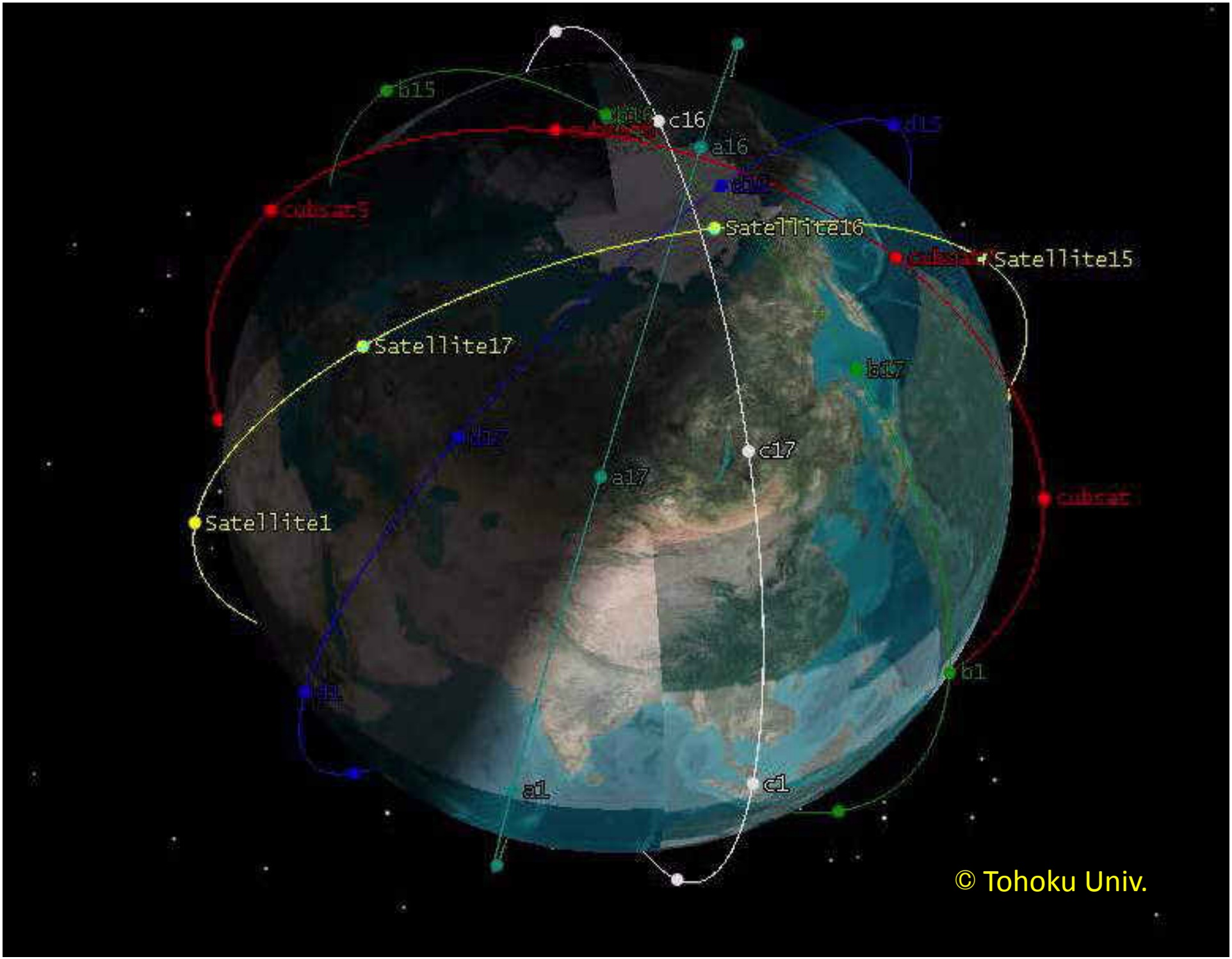
Asian Micro-satellite Consortium



Philippines

workshop with 6 countries

Myanmar


b15
c16
a16
Satellite16
Satellite15
Satellite17
b17
c17
a17
Satellite1
b1
a1
c1
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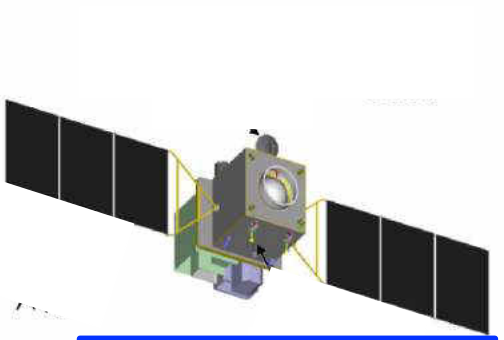
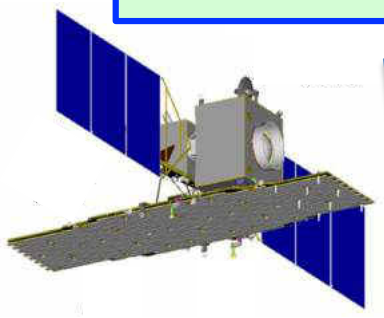
Space Remote-sensing Alliance



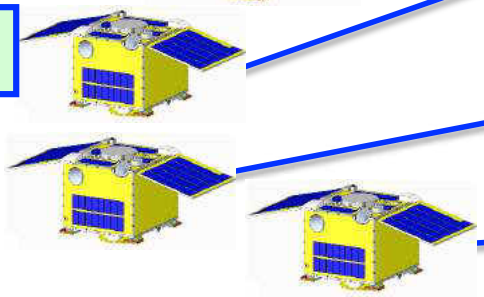
- detailed spectrum
- regular scanning

Hyper sensor satellites

SAR satellites



Micro-satellites



- flexible operation
- frequent monitoring
- super multicolor imaging
- SAR

country A

country B

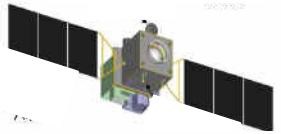
country C

country D

country E

Start-up of “the world first” ***Smart Remote Sensing***

Validation with small/middle sized satellite



On-demand operation using microsatellites

RISING-2

RISESAT

UNIFORM

Data downlink and analysis in SE-Asian countries

Bolometer Array Camera

- small, light, low power
- surface temperature
- forest fire detection

Telescopic Optics

- light (3kg) and compact
- maintenance free
- focusing free
- high-resolution (5m/pix)

LCTF Camera

- 400 bands (1nm step)
- 400-700 nm or 650-1050 nm covered
- small and compact

Regional measurement using UAVs

Wild Fire

bio diversity

CDOM

Micro-satellites and other ways including **UAV** with **standardized sensors** are operated as a **“network”**, maximizing data amount and satisfying specific requirement.

Toward next-generation remote-sensing with micro-satellite

Problems to overcome

- space debris
- risk management >>> constellation
- launch opportunity: both by government and private company
- selectivity of orbit: polar orbit + low inclination

Key to successful development

☑ International collaboration: concept is "sharing" and "standard instrument/method"

☑ Collaboration between space agency/governmental institutes and universities

☑ Understanding the roles of micro and larger satellites