

Workshop on
"Evaluation of the high-carbon reservoirs by integrated MRV system"

Innovating on
Earth/Climate Changing Observation
by liquid crystal tunable filter (LCTF)
on **Microsatellite**

--- a next generation tool for MRV ---

Yukihiro TAKAHASHI
Space Mission Center / Creative Research Institution
and
Dept. CosmoSciences / Graduate School of Science
Hokkaido University

Remote-sensing with satellite is doubtlessly one of the strongest measures to monitor the earth...

However:

Large or middle sized satellite

- takes large cost (1-few 100 M USD) and long period (>10 years)
- requires expensive but relatively conventional technologies
- is difficult to be optimized for individual purpose
- can observe only at rather long interval due to limited numbers.
- has huge risk even the "rate" of failure or trouble is quite small.

Paradigm Shift!

How to use the satellite data?



How to design and operate satellites
in order to get the necessary information

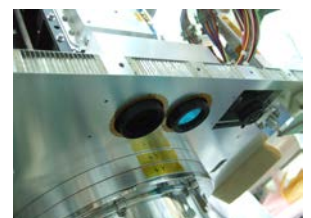
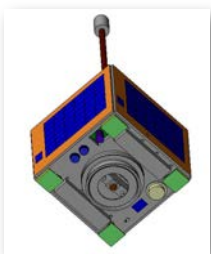
Advantages of 50 (or 100) -kg micro-satellite

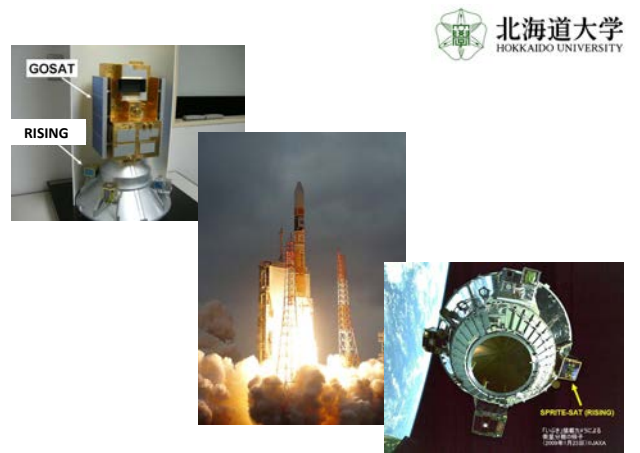
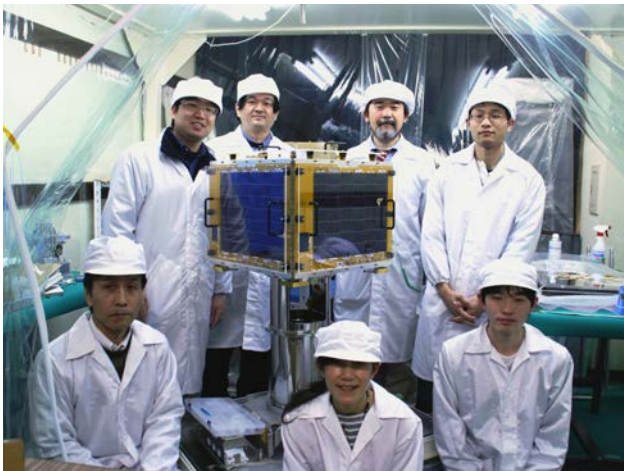
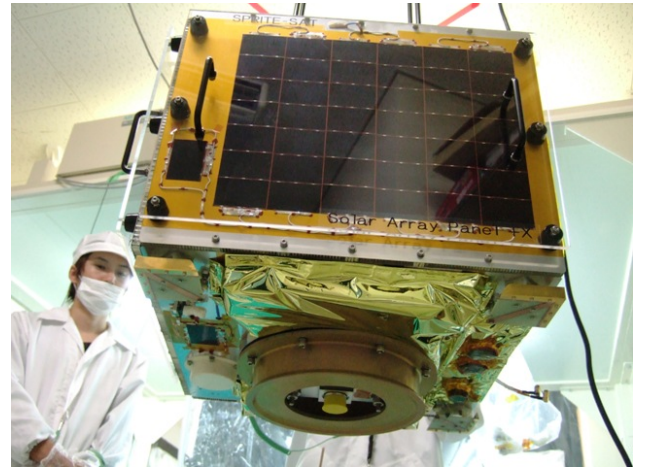
- not only for experiment but also for operational
- satellite downsizing is now going rapidly
- Low cost --- < few % of middle- or large sized satellite
 - <5 M USD including bus and mission payloads
 - commercial launch service: ~2-3 M USD
- Quick fabrication: about one year for flight model enabling application of the latest technologies
- On-demand operation
 - Users determine location, coverage/resolution, color, polarization, etc, based on their own purposes
- Constellation and network operation
 - enabling frequent monitoring from low altitude.
 - if 48 satellites in orbit, every 7.5 min monitoring possible

example of university micro-satellite:

RISING

50-cm, 50 kg, 3 M euro, including payload and BUS
fabrication completed in ~ 1 year
launched in 2009





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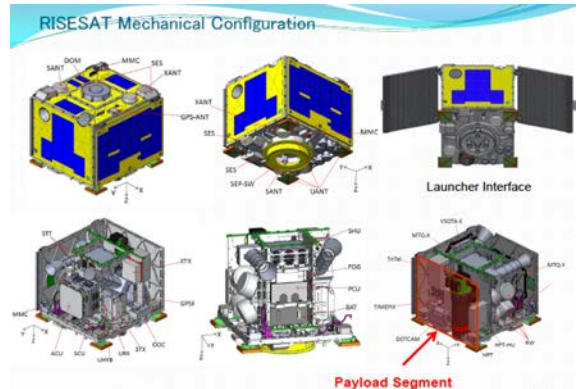
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Operated with a small dish on the top of university building..



Example of our advanced micro-satellite
"RISAT"

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RISESAT carries 6 scientific sensors

RISESAT Payload Instruments

Camera Instruments

- High Precision Telescope - HPT (Taiwan(NCU))
- Meteor counter - DOTCam (Taiwan(NCKU))
- Ocean Observation Camera - OOC (Hokkaido University)
- Technology Demonstration Laser Communication Transmitter (NICT, Japan)

Sensor Instruments

- TriTel - 3D Dosimeter (Hungary)
- TIMEPIX - Particle counter (Czech)
- MEMS Magnetometer (Sweden)

RISESAT System Specifications

Size and weight	Smaller than W 500 x D 500 x H 500 mm less than 55 kg
Orbit	type: Sun Synchronous Orbit local time: 9:00-15:00 (Default LTDN 11:00) altitude: between 500 - 900 km inclination: approx. 98 deg
Attitude determination and control	method: 3-axis stabilization pointing accuracy: $\langle 0.1^\circ \rangle$ (Req.), $\langle 0.04^\circ \rangle$ (Objectives) pointing stability: 6"/s sensors: star sensor (2), FOG (3-axes), magnetometer (3-axes), GPS receiver (1), course and accurate sun sensor(4) actuators: reaction wheels (4) magnetic torquers (3-axes)
Power supply	solar cells: GaAs multijunction cell 10 series x 5 parallel x 3 panels (Deployable panels and one body panel) 10 series x 1 parallel + 10 series x 2 parallel 9 series x 2 parallel NIMH (3.7Ah, 18V) battery unit: max. power generation > 100 W max. power consumption > 50 W
Communication	command uplink: UHF, 1200bps at Sendai station, Japan S-band, 0.1W, 38400bps - max. 5000bps main: Sendai station, Japan sub: Fukui Univ. of Tech. station, Japan sub: Kinama station, Sweden S-band, max. 2.4Mbps main: Fukui Univ. of Tech. station, Japan sub: Sendai station, Japan

Pointing accuracy: 0.04deg (3σ)
1.5 arcsec/100ms

Max power: >50 W

Downlink 2.4 Mbps

Launch configuration

After panel deployment

Now advanced technologies realize the high-quality measurements with micro-satellite...

Filter turret

mechanical rotation

LCTF camera

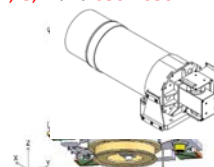
electric control

PARASOL/POLDER-3
weight: 32kg
of bands: 15

RISESAT/HPT
weight: 3kg
of bands: >630

High-resolution telescopic imaging system:

- HTP**
- compact (40cm), light(3kg), and strong (CFRP)
 - economical: ~0.5 M USD
 - zero expansion ceramic (ZPF) mirror
 - highly-functional CCD
 - gain range: 48dB, high-speed exp.: -1/50,000
 - high-resolution: 5 m/pixel
 - 4 CCD cover ~400 colors (R, G, B and 650-1050 nm with LCTF)
 - target pointing operation

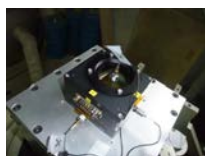


Hokkaido Univ. original technology

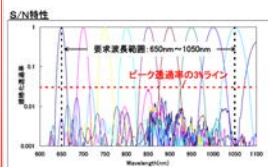
Liquid Crystal Tunable Filter: LCTF

attached to telescope

- S-NIR version 650-1050 nm
- Visible version 400-720 nm
- NIR version (planned) -2.4 nm
- FWHM=20 nm (5-20 nm)
- center wavelength 1 nm step
- change the color in 10-300 ms



- carbon fix in forest and agri. land red edge: 650-720 nm
- Identification of tree species
- carbon outflow in river and ocean CDOM (colored dissolved organic matters): 400-500s nm
- chlorophyll in ocean

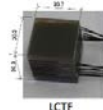


applicable to aircraft / ground-based use

Airborne Multicolor Imager (AMI)



- 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

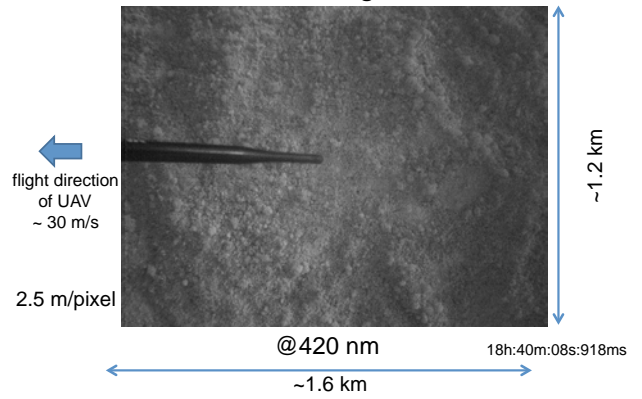


Specifications	
Wavelength range	420 - 700 nm
Band width (FWHM)	8 - 25 nm
Response time	< 0.3 sec
Frame rate	> 1 frame/sec
Number of pixels	659 x 494
Field of view	92 degree

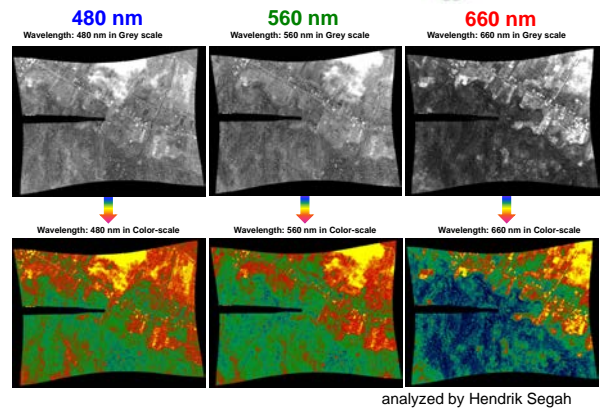
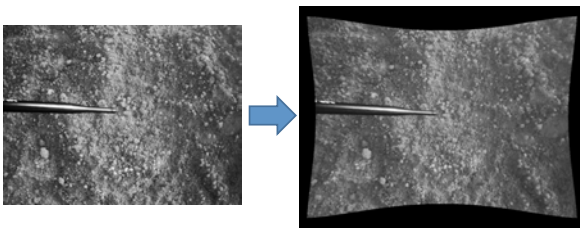
Aircraft (UAV) campaign with AMI in Java
(2012/10/29-31)



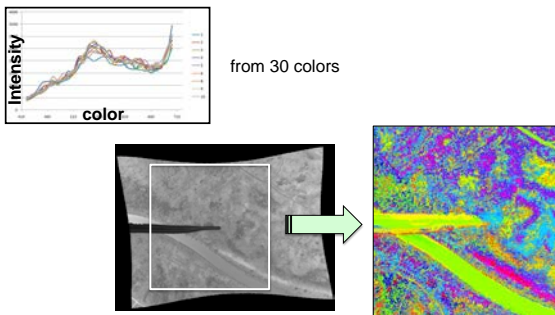
UAV developed and owned by BPPT



Geometric correction...



Multiple Endmember Spectral Mixture Analysis (MESMA)



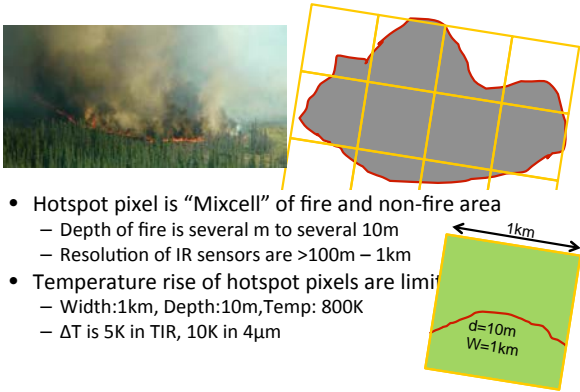
classification of species for each tree...

How to manage forest fires?

Micro Bolometer Array

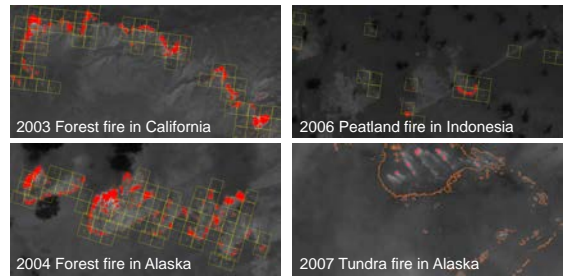
- Camera
- 10 μm (8-12 μm) camera which can image temperature distribution
 - Non-cooling system
 - small and light: 10cm, < ~1kg
 - inexpensive: ~0.1 M Euro
 - Heritage in Planet-C (Akastuki: Venus Climate Orbiter)
 - firstly developed "inexpensive version" for RISING-2 (1-2 km/pix)
 - Main payload of UNIFORM-1 with spatial resolution of 150 m/pixel





- Hotspot pixel is "Mixcell" of fire and non-fire area
 - Depth of fire is several m to several 10m
 - Resolution of IR sensors are >100m – 1km
- Temperature rise of hotspot pixels are limited
 - Width:1km, Depth:10m, Temp: 800K
 - ΔT is 5K in TIR, 10K in 4μm

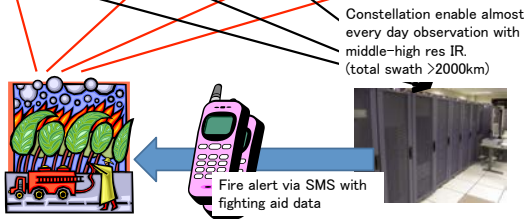
Simulated fire detection with high-res. TIR images.



Hokkaido University plays main role in organizing satellite data for fire detection

Fire location: geolocationally accurate (115-250m) with Japanese new sensors

UNIFORM-1 UNIFORM-2,3 FY2013	SGLI on GCOM-C1 FY2015	CIRC on ALOS-2 FY2013	CIRC/CALET on JEM/ISS FY2014	ASTER on Terra operation	OLI on LANDSAT8 FY2012
Swath:100km Resol: 200m	Swath:1150km Resol: 250m	Swath:130km Resol: 200m	Width:80km Resol: 115m	Swath:60km Resol: 90m	Swath:185km Resol: 30m



Constellation enable almost every day observation with middle-high res IR. (total swath >2000km)

Fire alert via SMS with fighting aid data

SATREPS (Indonesia): 北海道大学 HOKKAIDO UNIVERSITY

Fire alert via SMS with fighting aid data

Relative location from villages

Fire location		Linear Distance	Road access	GWT
Lat	Long	Dist ↓	Direction ↓	
2012-08-01 (No Hotspot detected (No fire, weak fire or no satellite data))				
2012-08-02 (2 Hotspots detected, 0 are accessible from the highway)				
2.683S	114.299E	19.295m	141 SE	-44cm
	4.298E	19.507m	142 SE	-44cm

Wildfire Map (Satellite data)

Map literacy is a hidden key how to send an alert from the fire monitoring system. If fire fighters can not read maps → we need to send relative location data via SMS.

SMS Alert

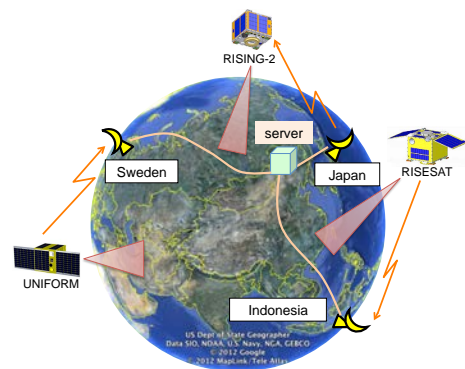
Fire at 5km from Pilang toward PKY. Fire spreads to Pilang. Dry, fast.

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LCTF telescope (R-G-B, and 650-1050nm)
Thermal Infrared Camera (2km resolution)
launch: 2013.3

UNIFORM
Thermal Infrared Camera (150m resolution)
launch: 2013.3

RISESAT
LCTF telescope (420-650 nm, 650-1050nm)
with BPPT(Indonesia), NCU (Taiwan)
launch: 2014 (planned)



first experiment of Smart Remote Sensing (2014)

Smart Remote Sensing with Super-Constellation



10 micro-satellites in equatorial orbits enables 10-min interval monitoring

Smart Remote Sensing with Super-Constellation with standardized sensors



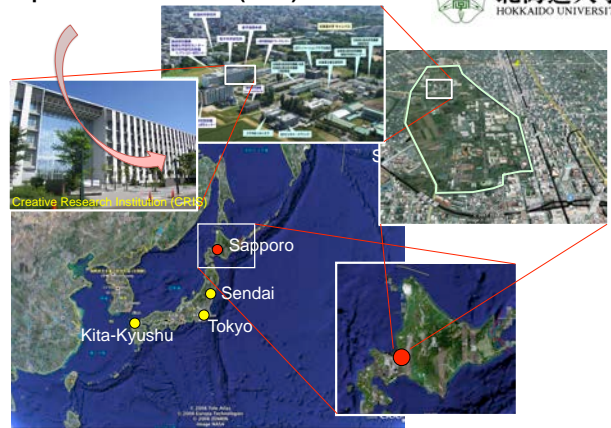
48 satellites in polar orbits = every 7.5 min (ave.) at any location in the world



How to start space development with micro-satellite?

- join the operation of our micro-satellites
let's take pictures of your city or forest area and receive the data at your place
- send your staffs/students to Hokkaido University for capacity building (short course – PhD course) development of satellite and data analysis
- make measurement on the ground or aircraft
- develop your own satellite and payload by yourself and join the super-constellation

Space Mission Center (SMC) of H.U.



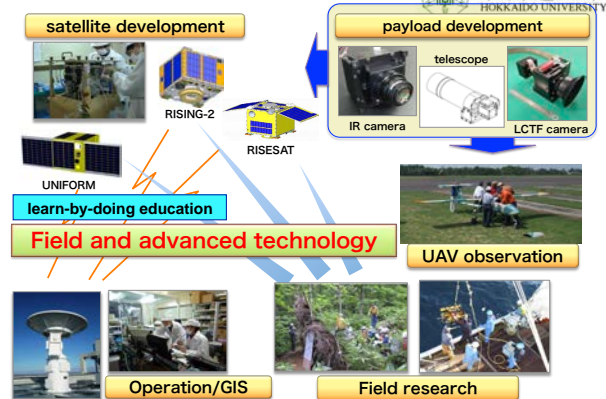
Facilities for development and testing in microsatellite development lab.



One stop site for micro-satellite development



- Thermal chamber
- Thermal vacuum chamber
- Vibration test facility,
- Shock test facility,
- Radio wave darkroom are available at Hokkaido Research Organization
- Class 100 clean booth and darkroom

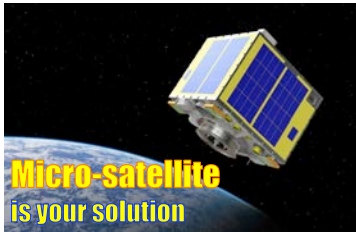




"we are happy to support your every space activity"

with technical assistance and capacity building on:

mission design, bus / payload development, environmental testing, launch, operation, data analysis



Contact: Prof. Yukihiro TAKAHASHI,
yukhiro@mail.sci.hokudai.ac.jp
URL; http://www.cris.hokudai.ac.jp/cris/smc/index_e.html