COP19, Warsaw, 13 November, 2013

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

北海道大学 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.

北海道大学 HOKKAIDO UNIVERSITY

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

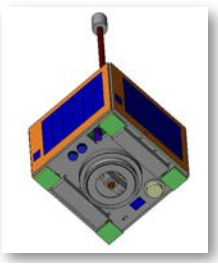
- On-demand operation
  Users determine location, coverage/resolution,
  color, polarization, etc, based on their own purposes

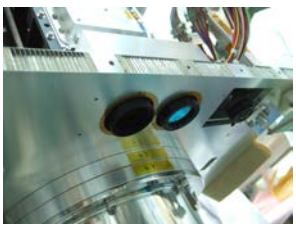
- Constellation and network operation
  enabling **frequent monitoring** from low altitude.
  if 48 satellites in orbit, every 7.5 min monitoring possible

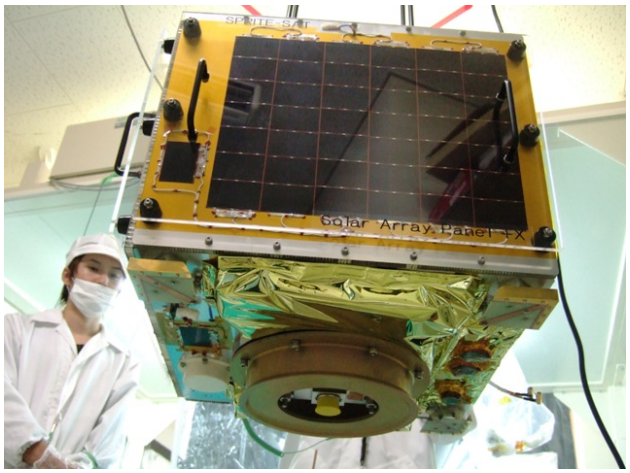
北海道大学 HOKKAIDO UNIVERSITY

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







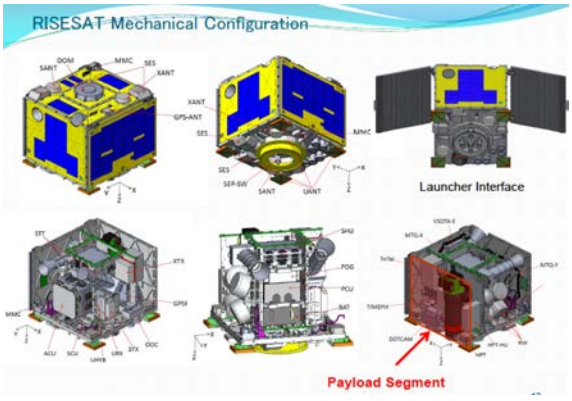
北海道大学
HOKKAIDO UNIVERSITY

北海道大学
HOKKAIDO UNIVERSITY

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

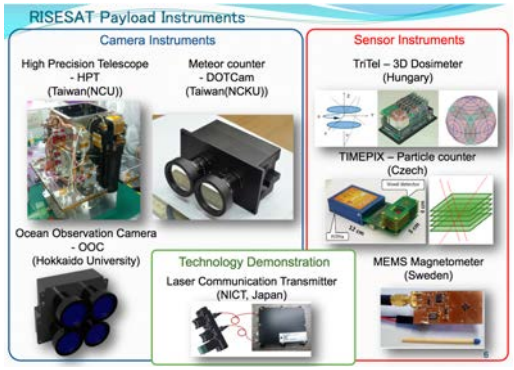
Example of our advanced micro-satellite "RISESAT"

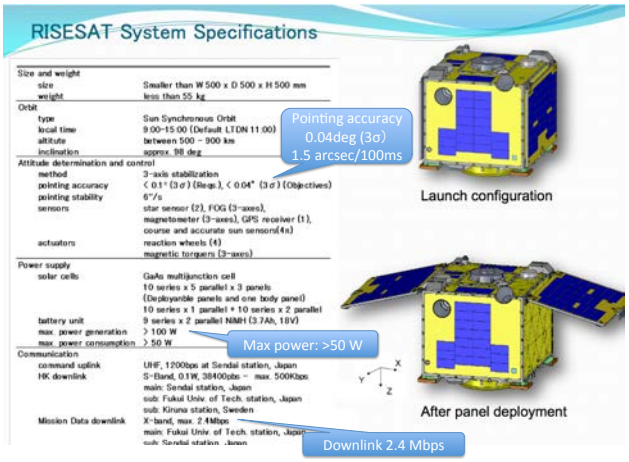
北海道大学
HOKKAIDO UNIVERSITY



北海道大学 HOKKAIDO UNIVERSITY

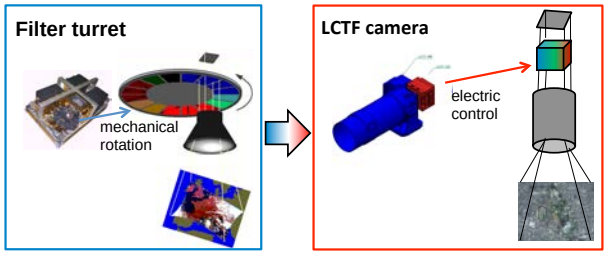
RISESAT carries 6 scientific sensors





北海道大学 HOKKAIDO UNIVERSITY

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



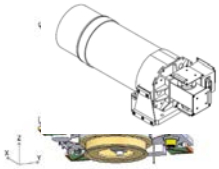
PARASOL/POLDER-3
weight : 32kg
# of bands : 15

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

北海道大学 HOKKAIDO UNIVERSITY

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



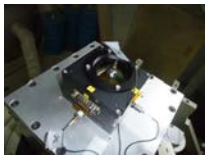
北海道大学 HOKKAIDO UNIVERSITY

Hokkaido Univ. original technology

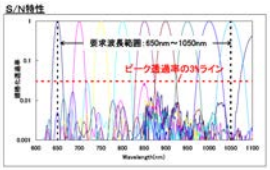
Liquid Crystal Tunable Filter: LCTF

attached to telescope

S-NIR version 650-1050 nm
Visible version 400-720 nm
NIR version (planned) -2.4 um
- 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**



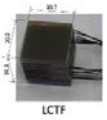
北海道大学 HOKKAIDO UNIVERSITY

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


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

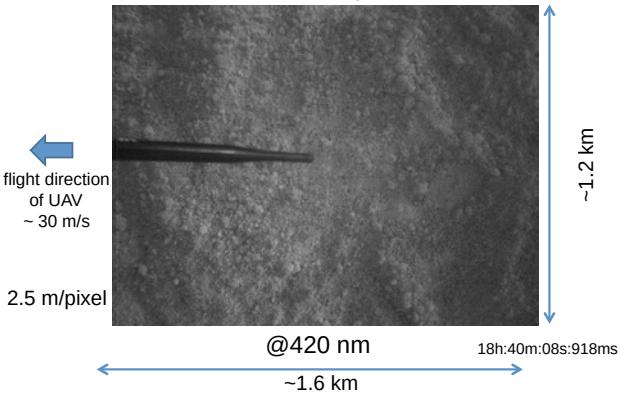
北海道大学 HOKKAIDO UNIVERSITY

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

UAV developed and owned by **BPPT**

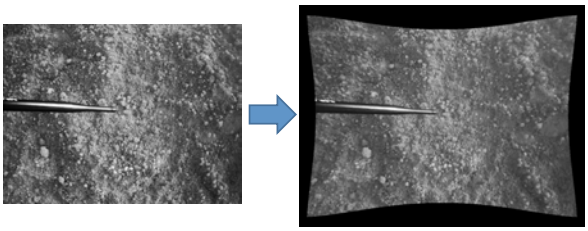
北海道大学 HOKKAIDO UNIVERSITY

10/31 ~18:40
forest in the target area

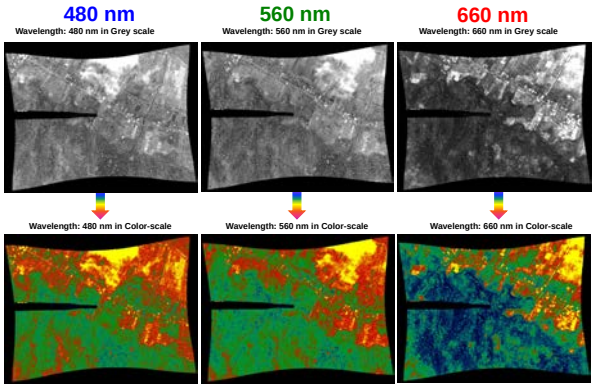


北海道大学 HOKKAIDO UNIVERSITY

Geometric correction...



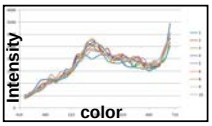
北海道大学 HOKKAIDO UNIVERSITY



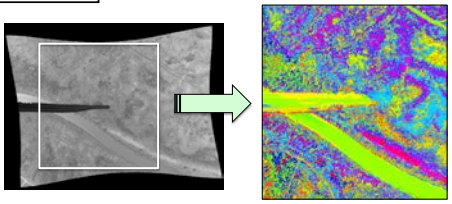
analyzed by Hendrik Segah

北海道大学 HOKKAIDO UNIVERSITY

Multiple Endmember Spectral Mixture Analysis (MESMA)



from 30 colors



classification of species for each tree...

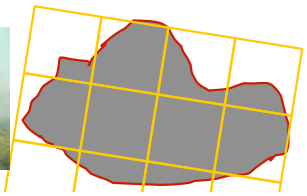
北海道大学 HOKKAIDO UNIVERSITY

How to manage forest fires?

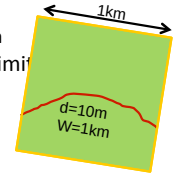
Micro Bolometer Array Camera

- 10 μm (8-12 μ) 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

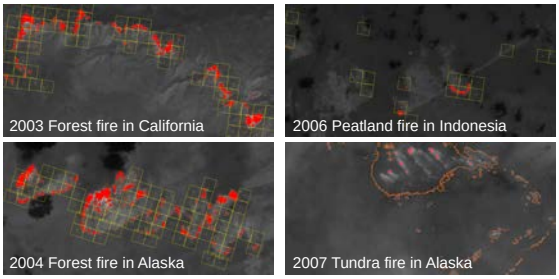
Wildfire from space



- 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 limi
  - Width:1km, Depth:10m,Temp: 800K
  - ΔT is 5K in TIR, 10K in 4μm

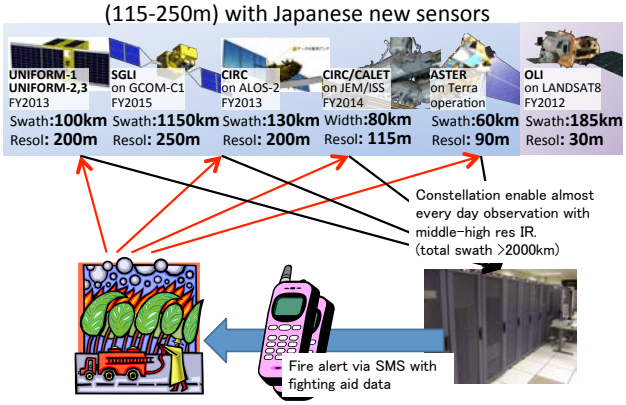


Simulated fire detection with high-res. TIR images.

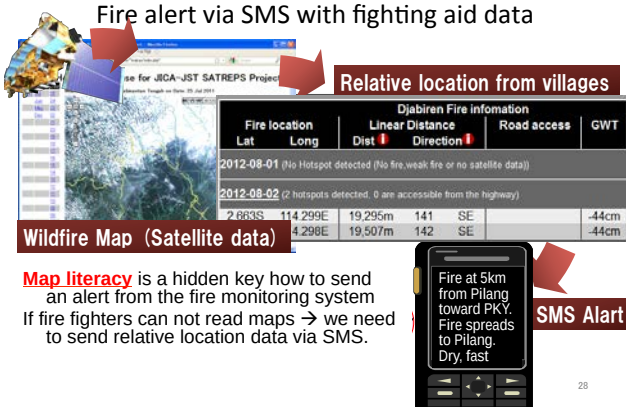


Hokkaido University plays main role in organizing satellite data for fire detection

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

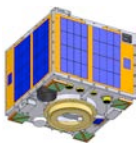


SATREPS (Indonesia):
Fire alert via SMS with fighting aid data



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.

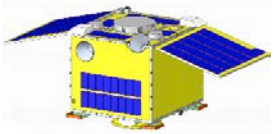
LCTF telescope
(R-G-B, and 650-1050nm)
Thermal Infrared Camera
(2km resolution)
launch: 2013.3



RISING-2

UNIFORM

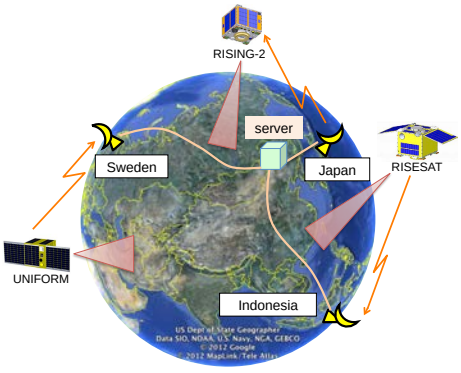
Thermal Infrared Camera
(150m resolution)
launch: 2013.3



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

北海道大学 HOKKAIDO UNIVERSITY

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

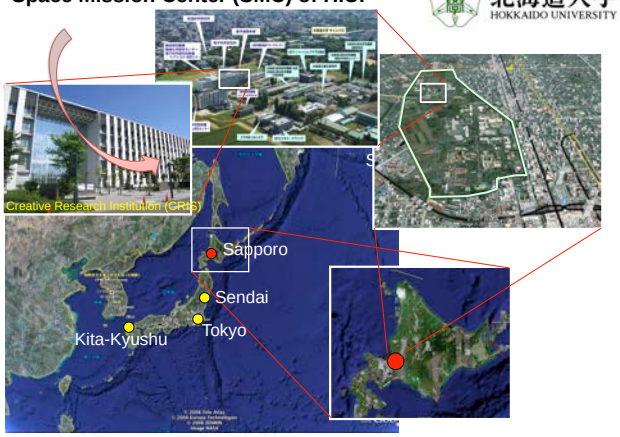
- send your staffs/students to Hokkaido University
  for capacity building (short course – PhD course)
  development of satellite and data analysis

- 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.

北海道大学 HOKKAIDO UNIVERSITY



Facilities for development and testing in microsatellite development lab.

北海道大学 HOKKAIDO UNIVERSITY

One stop site for micro-satellite development

■ Thermal chamber

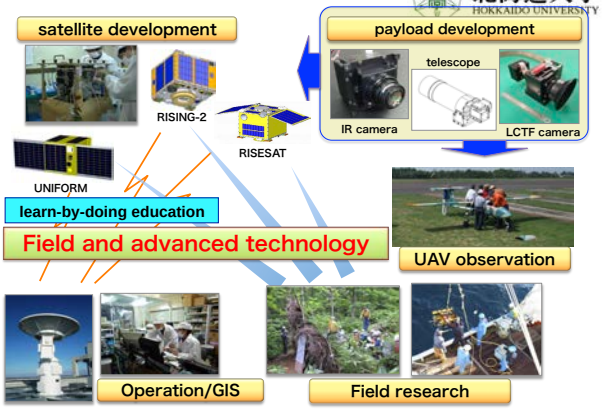
■ Thermal vacuum chamber

■ Class 100 clean booth and darkroom

■ Vibration test facility,
■ Shock test facility,
■ Radio wave darkroom

are available at Hokkaido Research Organization

北海道大学 HOKKAIDO UNIVERSITY

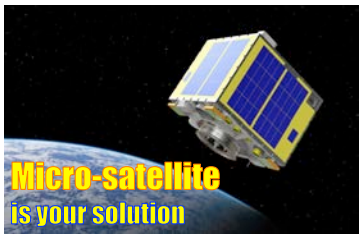


北海道大学
HOKKAIDO UNIVERSITY

"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



Hokkaido University / Creative Research Institution
Space Mission Center

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