WHAT’S THE BIG DEAL ABOUT SMALL SATELLITES

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NANYANG TECHNOLOGICAL UNIVERSITY
THE UNIVERSITY OF COLORADO-BOULDER

- Flagship teaching and research university of the Colorado university system
- Largest undergraduate astronomy/astrophysics program in the US
- Top-5 NRC rankings for graduate programs in APS, Physics, and Aerospace Engineering
- NSF top-5 public (top-10 overall) institutions in federally-funded research
- The top public US institution in NASA funding
Van Allen Probes Mission
LASP’s REPT Instrument
Provides Space Weather Data

New Horizons – Student Dust Counter
Pluto Fly-by – July 2015

- MAVEN is studying Mars’ upper atmosphere, ionosphere, magnetosphere, and their interactions with the Sun and solar wind
- The goal is to understand stripping of the atmosphere to space and its influence on the history of Mars climate
The Emirates Mars Mission (EMM) is a strategic initiative and vision of the UAE, announced in July 2014.

In an international collaboration the Mohammed Bin Rashid Space Centre, partnered with CU/LASP, will implement the mission and design, build and operate the EMM spacecraft, to arrive in Mars orbit in 2021.

EMM is in Phase C and on schedule for a July 2020 launch.
Gravity wave observations in the summertime polar mesosphere from the Cloud Imaging and Particle Size (CIPS) experiment on the AIM spacecraft

A. Chandran\textsuperscript{a,b,1}, D.W. Rusch\textsuperscript{b}, S.E. Palo\textsuperscript{b}, G.E. Thomas\textsuperscript{b}, M.J. Taylor\textsuperscript{c}

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Polar mesospheric cloud structures observed from the cloud imaging and particle size experiment on the Aeronomy of Ice in the Mesosphere spacecraft: Atmospheric gravity waves as drivers for longitudinal variability in polar mesospheric cloud occurrence

A. Chandran,\textsuperscript{1,2} D. W. Rusch,\textsuperscript{1} A. W. Merkel,\textsuperscript{1} S. E. Palo,\textsuperscript{2} G. E. Thomas,\textsuperscript{1} M. J. Taylor,\textsuperscript{2} S. M. Bailey,\textsuperscript{3} and J. M. Russell III\textsuperscript{3}


Atmospheric gravity wave effects on polar mesospheric clouds: A comparison of numerical simulations from CARMA 2D with AIM observations

A. Chandran,\textsuperscript{1,2,3} D. W. Rusch,\textsuperscript{1} G. E. Thomas,\textsuperscript{1} S. E. Palo,\textsuperscript{2} G. Baumgarten,\textsuperscript{4} E. J. Jensen,\textsuperscript{5} and A. W. Merkel\textsuperscript{1}

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journal homepage: www.elsevier.com/locate/jastp
THE COLORADO SPACE WEATHER EXPERIMENT

LASP Cubesats

- Funded by the NSF
- Launched in 2012
- operated for 28mo
- Collected over 100MB of Science Data
- Generated over 19 peer reviewed publications

Relativistic Electron Proton Telescope

The Miniature X-ray Solar Spectrometer

- First NASA SMD CubeSat
- Launched Dec 6, 2015
- Deployed May 2016
- Achieved full success
- S/N 001 BCT XACT
- Coordinated in AES projects course
- Reentry May 2017
- MinXSS-2 scheduled to launch 2Q17
A partnership between **IIST (ISRO’s flagship University)** and **CU Boulder (The largest NASA funded University)** has acted as a catalyst to form an international consortium of Universities doing research in space science and engineering.

**INSPIRESAT1- A cubesat for Ionospheric studies**
INSPIRESat-1 Summary

INSPIRESat-1 – Science Objectives

- Observe occurrence and evolution of equatorial Plasma bubbles.
- Observe Midnight Temperature Maximum features.
- Observe Ion/electron temperatures, density and velocities

The Compact Ionosphere Probe consists of a Planar Langmuir Probe, Retarding Potential Analyzer, Ion Trap and Ion Drift Meter

INSPIRESat-1 Breakdown of Responsibilities

- INSPIRESat-1 is schedule for launch in 2019 on an ISRO PSLV
- The satellite is being built joint by CU, NCU (Taiwan) and IIST (India)
Under the INSPIRE Consortium, three launches are to be provided in 2019, 2021 and 2023 on board ISRO PSLV.

**INSPIRESat-1** – Funded and built by **CU Boulder, IIST** and **NCU Taiwan** with support from NTU

**INSPIRESat-2/IDEASSAT**
Funded by **National Space Organization of Taiwan (NSPO)**
Built jointly by NCU Taiwan, CU Boulder and IIST

**INSPIRESat-3**
Funded by **NTU Singapore**
Built jointly by NTU, CU Boulder and IIST.
INSPIRE – BENEFITS TO NTU & SINGAPORE

• Provides access to space for participating Universities and other entities
• Can be used to raise *Technology Readiness Level* of prototype technologies.
• Develops an innovative hardware oriented ‘hands-on’ curriculum for teaching spacecraft engineering and instrumentation.
• Distributing cost of a satellite mission among partners makes missions affordable.
• INSPIRE acts as a forum for bringing together students, engineers and scientists.
• Builds a collaborative attitude in future international space leaders.
• Helps to learn from best practices, shared knowledge and expertise
INSPIRESAT-1 SCIENCE OBJECTIVES

2. Observe Midnight Temperature Maximum features.
3. Observe Ion/electron temperatures, density and velocities

GIF courtesy of Chi-Ting Liao
INSPIRESAT-1, IDEASSAT (INSPIRESAT-2) MISSION DESIGN
SaRC - Satellite Research Centre

X-SAT

World first zigbee network in space

Celebrated its 6th year anniversary

In orbit since 20 April 2011. It captures more than 9000 high resolution images.

VELOX-I

A climate research satellite using radio occultation.

In orbit since 16 Dec 2015.

The first student built satellite.

In orbit since 21 Nov 2013.

VELOX-PII

The smallest satellite with iPhone size, 193g. In orbit since 30 June 2014.

VELOX-CI

A climate research satellite using radio occultation.

In orbit since 16 Dec 2015.

Inter-satellite communication demonstrating anywhere anytime up and down link.

In orbit since 16 Dec 2015.

VELOX-PIII

The world's first Zigbee network in space

In orbit since 16 Dec 2015.

VELOX-II

A Pulse plasma thruster demonstration satellite.


AOBA VELOX-III

Inter-satellite communication demonstrating anywhere anytime up and down link.

In orbit since 16 Dec 2015.

Pulse plasma thruster demonstration satellite.

COSMIC 1 & 2
416 kg satellite constellation that demonstrated the use of GPS RO for weather forecasting and use in data assimilation models.

- Total Electron Content Measurements
- Vertical profiles of atmospheric temperature
- Vertical profiles of water vapour.

Lemur-2 from SPIRE
4 kg 3U cubesat. A constellation of SPIRE satellites are expected to provide commercial weather data.
RO EXPERIENCE AT SARC

- Total mission data collected 2.48 GB.
- 194 missions which covered 340 orbits.
- Map showing over 1,600 radio occultation events.

Courtesy of Dr. Bingxuan Li
VELOX-CI RO PERFORMANCE

Indications of possible Gravity Wave activity

Comparison with SABER instrument on-board NASA TIMED satellite

Courtesy of Dr. Bingxuan Li
REGIONAL IONOSPHERIC MAPPING AND AUTONOMOUS UPLINK (RIMAU) CONSTELLATION

- RIMAU is proposed to be an equatorial constellation carrying the compact ionosphere probe and a GPS radio occultation payload.
- RIMAUSat-1 can demonstrate common volume TEC measurements with ground based GPS receivers.
- CIP will provide information of fine-scale Ionospheric structure. A constellation (8 satellites) can provide continuous common volume measurements and provide an unprecedented opportunity to map the ionosphere regionally.

(More ground based receivers/occultation points ➔ higher resolution mapping)
ADVANTAGES OF RIMAU

Three dimensional regional ionosphere observations can lead to:

• new discoveries on equatorial plasma structure.

• Better characterization of Ionospheric effects on communication range, outages, scintillation effects on GPS etc.

• Better understandings on:
  o atmosphere-ionosphere coupling
  o solar wind effects
  o seismic effects

• Development of Ionosphere forecast model.

• Provide continuous vertical profiles of temperature and water vapor which can have huge implications for regional weather forecasting.
HYPER SPECTRAL IMAGING

HYPER SPECTRAL Imager for Climate Science (HYSICS) PI- Prof. Greg Kopp, LASP, CU

A single focal plane array spans the entire spectral region, allowing for reduced mass, volume, and complexity for space flight applications.

HYSICS covers the reflected solar spectrum between 350-2300 nm at 6 nm spectral resolution with a 0.5 km spatial resolution from low Earth orbit.

HYSICS can be used in determination of atmospheric composition, land usage, vegetation, and ocean color.

Technical challenges

- Precision pointing
- High mass (~ 20 kg)
- Very high data rates
- High power
KEY TECHNOLOGY ENABLERS – TECHNOLOGY RESEARCH AREAS

• Precision pointing
  • less than 30 arc second pointing knowledge ➔ We need attitude control system with star tracker

• High data rate communication to bring down large data volumes.
  • Use of multiple ground stations

• Electric propulsion technologies
  • Longer duration, innovative mission ideas.

• Deployable mechanisms
  • larger solar panels and phased array antenna’s.

• Thermal control
To be a world class centre for advanced research and training in innovative space technologies for small satellite system

- Pursue satellite missions with high scientific and regional relevance.
- Build up data analysis and atmospheric modelling expertise.
- Collaborate with groups both regionally and internationally to expand knowledge base in critical technology areas.
- Make international partnerships to enable access to space.
- Work with local industry and foster start up growth in key technology enabler areas.
- Train the next generation workforce of engineers and scientists.

Thank you for your attention!