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Session 1: Project Reports
Ground Operation Analysis of an Advanced Satellite in Near Equatorial Orbit

presented by

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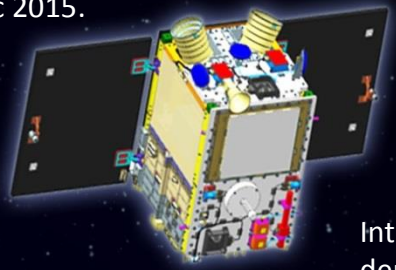
SaRC - Satellite Research Centre

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

VELOX-CI

A climate research satellite using radio occultation.
In orbit since 16 Dec 2015.



VELOX-II

Inter-satellite communication demonstrating anywhere anytime up and down link.
In orbit since 16 Dec 2015.

AOBA VELOX-III

Pulse plasma thruster demonstration satellite.
Scheduled for launch in 2016.

VELOX-I

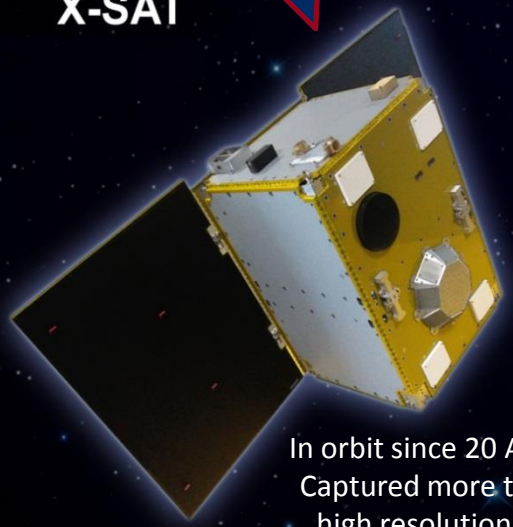
Demonstrated world's first ZigBee network in space.

VELOX-PIII

The smallest satellite of iPhone 5 size, 193g. In orbit since 30 June 2014.

X-SAT

Celebrated its 5th year anniversary this year



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

VELOX-PII

The first student built satellite.
In orbit since 21 Nov 2013.

Agenda

- VHF/ UHF Ground Station in NTU
  - Limitations of the Ground Station
- VELOX-I Overview
  - Lessons Learned
- VELOX-II Overview
  - Ground Operation Requirement
  - Autonomous Ground Station
  - Ground Station Maintenance
  - Experiments Conducted
- Summary
- Future Plans

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VHF/ UHF Ground Station

- Setup by undergraduates in the Undergraduate Satellite Program (USP) in 2010
- Licensed and approved by Info-Communications Development Authority of Singapore (IDA) to track and communicate with Pico- and Nano satellites
- Assigned “9V1SG” call sign; Radio Amateur Operators
- Grid Location: “0J11UI” (Jurong West)
- Conducted operations for VELOX-PII and VELOX-I
- Currently tracking and performing real time operations for VELOX-II

Ground Station: Located in NTU

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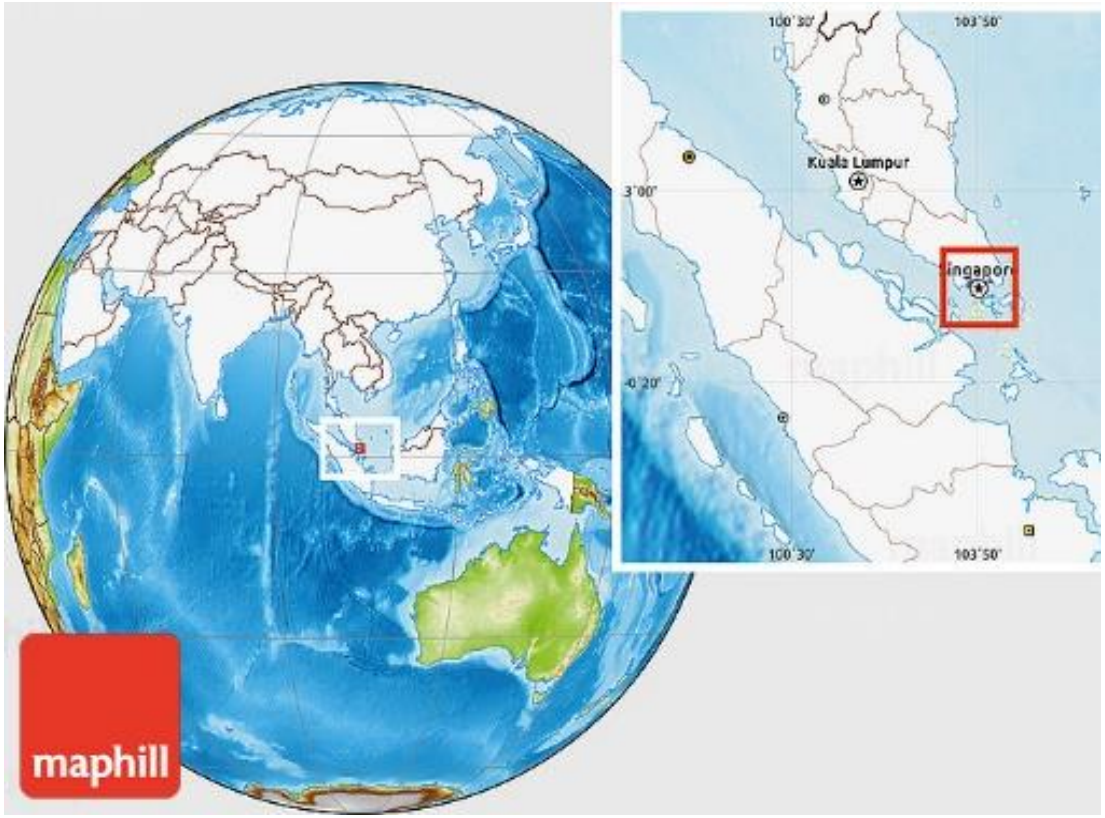
VHF/ UHF Ground Station- Limitations

- Geographical location of Singapore: Near the equator, frequently experiencing tropical climate (Rain, Lightning)
- Located within a busy sea port and an urban environment; Interference
- Approximately 10–12 minutes contact per pass; Further reduces space to ground communication



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VHF/ UHF Ground Station- Limitations

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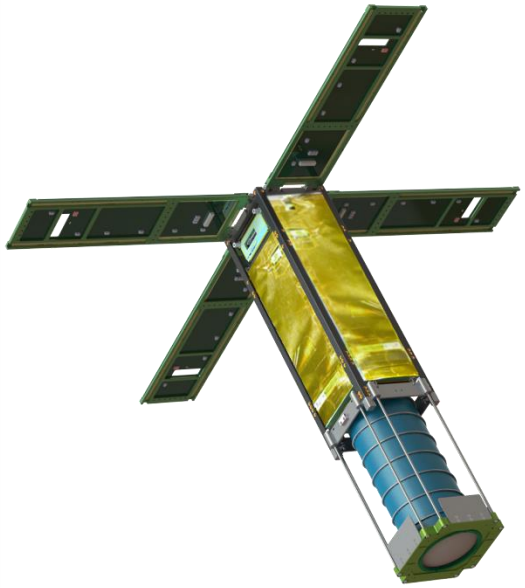
VELOX-I Overview

Dimensions	100mm x 100mm x 340mm (VELOX-I), 60mm x 70mm x 30mm (VELOX-PIII)
Mass	4088 grams (VELOX-I), 193 grams (VELOX-PIII), total 4281 grams
Expected lifetime	12 months (VELOX-I), 6 months (VELOX-PIII)
Orbit	**Sun-synchronous low earth orbit (LEO), 650 – 700 km altitude**
Attitude determination and control system	(VELOX-I) 3-axis stabilized and controlled with 1 GPS receiver, 2 IMUs, 1 dual-FOV sun sensor, 8 coarse sun sensors, 3 magnetic torquers and 3 RWs
On-board data handling	Mainboard with 100MHz 8051 MCU, 2Gb SD card, UART and I^2C data interfaces
Communications	9600bps BPSK downlink / 1200bps AFSK uplink, UHF & VHF dipoles
Power subsystem	(VELOX-I) 4 deployable GaAs panels for 28.8W peak, 5200mAh Li-ion battery
Structure	Al. 7075 chassis, with stainless steel/Ti-6Al-4V load bearing parts; spring-loaded separator, solar panel deployer, and optics extension mechanism
Thermal control	Multi-Layer Insulation (MLI) and battery heaters
Payloads	Vision system with extended optics for 20m GSD, GPS payload for precision navigation



VELOX-I: Revisits Singapore 4 times a day

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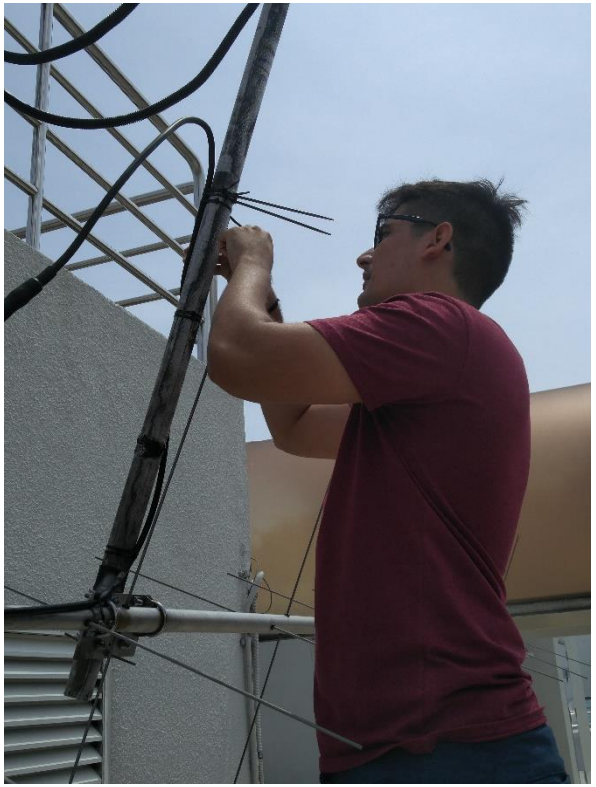
VELOX-I: Lessons Learned

- 4 passes (2 mornings, 2 evenings)
  - Evening passes are from the West, generally better
  - Require additional manpower to operate the ground station in the evenings
- Passes with < 10° elevation experience signal degradation
- Low data rate; more passes required to download data
- During rain or thick cloud formation, no ground pass can be established
- Conduct visual inspection of mechanical assemblies periodically (rotators, antennas, cable works)
- Need for an autonomous ground station (VELOX-II)



Ground Station: Cabling reworks.

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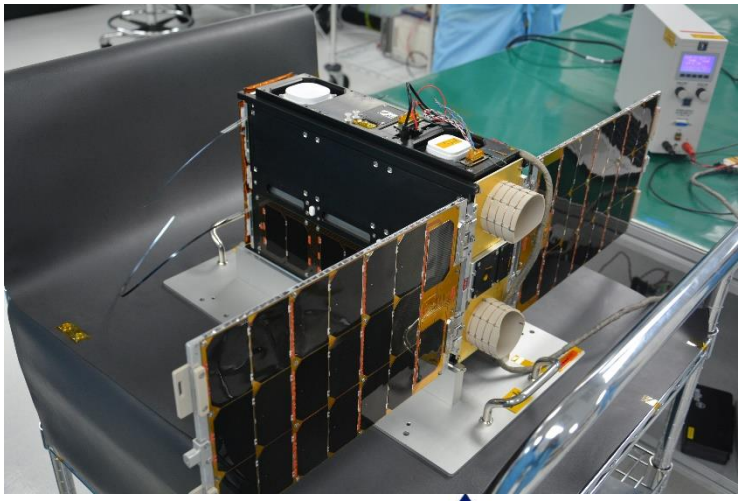
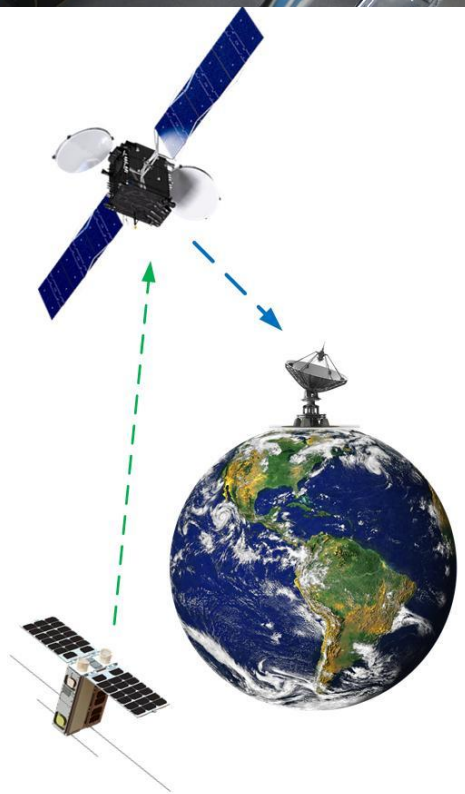
VELOX-II OVERVIEW

- 6U CubeSat
- Carrying primary payload designed by local company Addvalue Innovation
- Experimental communication payload is to exhibit Inter Data Relay System (IDRS) with higher orbiting satellite
- Conduct inter-satellite communication and relay relevant data to ground station, which can then be accessed via telnet
- Ability to demonstrate "data downlink anywhere, anytime in orbit" without the need of acquiring Line of Sight (LOS) when flying over Singapore





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VELOX-II OVERVIEW

VELOX-I: Revisits Singapore 4 times a day

	Overview of VELOX-II
Dimensions	120 mm x 246 mm x 340.5 mm in stowed
Mass	9 kg (satellite)
Orbit	Near equatorial LEO orbit, 550 km altitude
ADCS	2 IMUs, 4 fine and 8 coarse sun sensors, 3 torquers, 3 reaction wheels
Communication	9600bps AFSK 437.305 MHz, 1200bps BPSK AX-25 beacon
OBDH	100 MHz 8051 MCU, 2 GB SD card, UART and I2C interfaces
PSS	2 deployable GaAs 6U panels (2s5p, 40 W peak), 2 GaAs 3U panels (2s3p, 12 W peak), Li-ion batteries @ 7.2 V nominal)
Thermal control	Multi-Layer Insulation (MLI)
Structure	AL 7075 chassis, with stainless steel/Ti-6A1-4V bearing parts; spring-loaded separator, solar panel
Payloads	Primary communication payload (IDRS), GPS fault tolerant electronic circuit

VELOX-II: Revisits Singapore up to 14 times a day.

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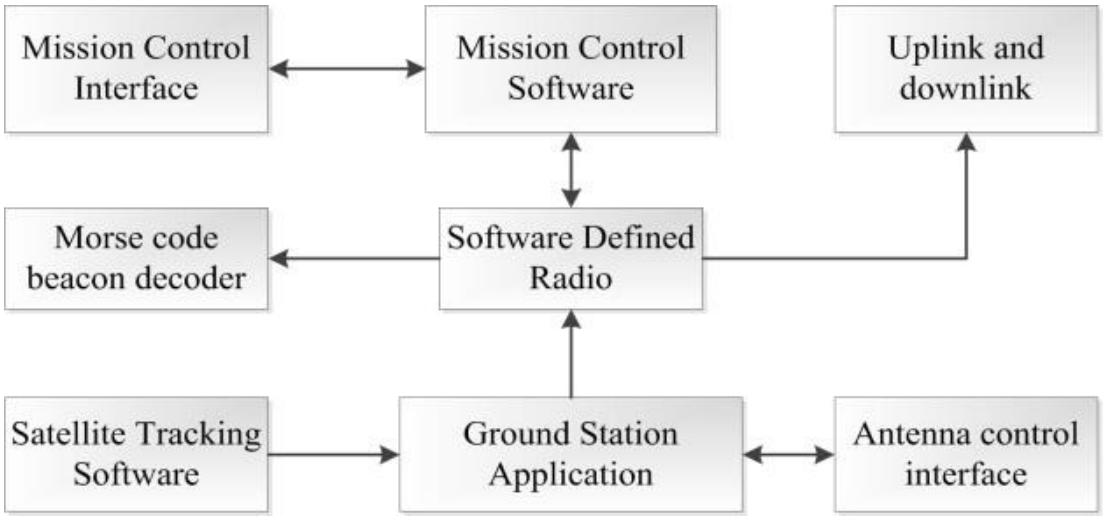
VELOX-II Ground Operation

For VELOX-I:

- Operators manned most passes manually



Requirement for VELOX-II:

- 24/7 ground operation (Higher revisits)
- Minimize ground operation manpower

Solution:

- Autonomous Ground Station

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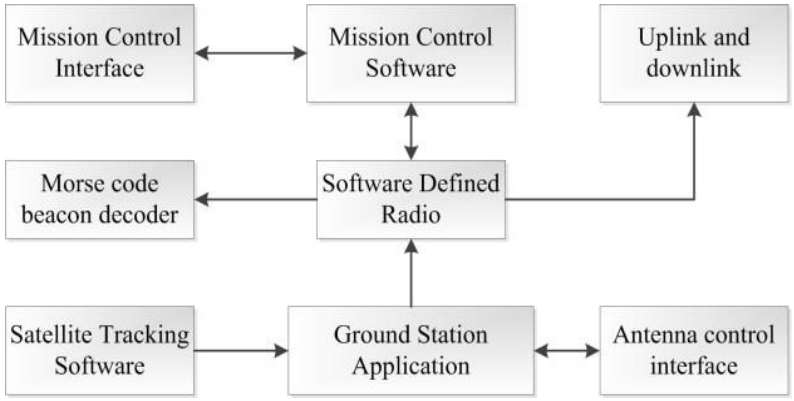
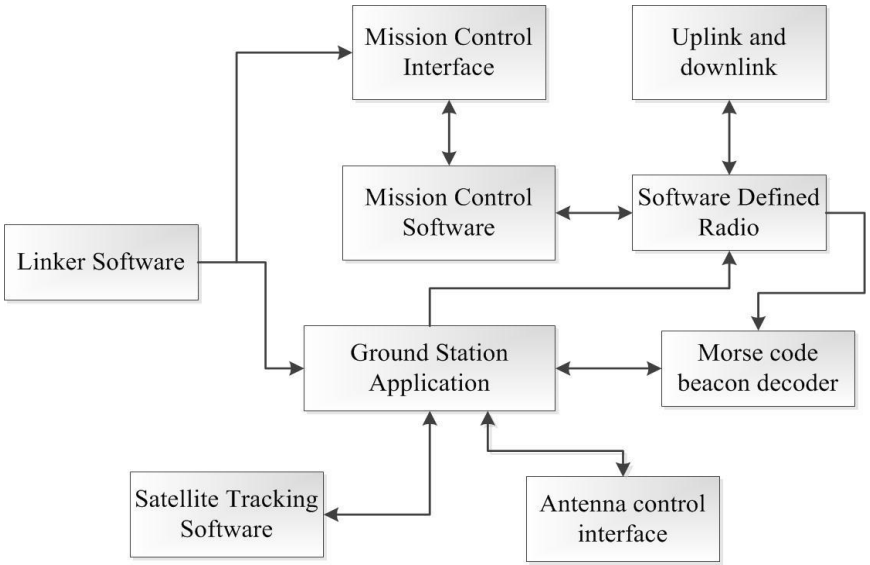
Autonomous Ground Operation





- New linker software to link both flight control and ground antenna control software
- Enable flight control and ground antenna control interface to be commanded by linker
- Critical applications always OFF except during ground pass period
- Non-critical applications always ON

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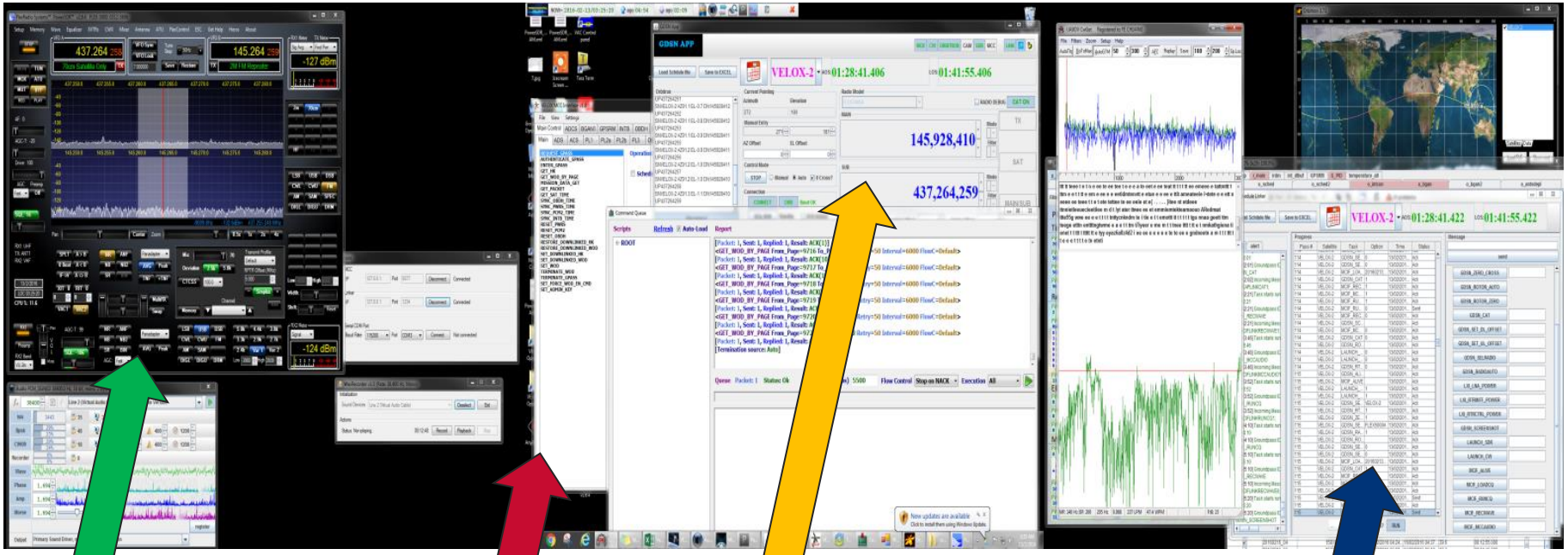
Autonomous Ground Operation



Software Defined Radio

Flight control interface

Ground control interface

Linker software

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Autonomous Ground Station

- Intensive operations
  - 14 to 15 passes per day
  - Approximately 3640 passes (260 days * 14 pass/day) as of 31 Aug 2016
  - Fully-automated operations
  - Power cycle equipment weekly
- Maintenance
  - Rotator replacement
    - 30 Apr to 11 May 2016
  - Routine maintenance
    - 29/30 Sep 2016

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VELOX-II Experiments Conducted

Experiment	Date	Status
Inter-satellite communication #1	22 Dec 2015	Fail
Inter-satellite communication #2	27 Dec 2015	Fail
Inter-satellite communication #3	20 Jan 2016	Success
Inter-satellite communication #4	26 Feb 2016	Success
Inter-satellite communication #5	01 Mar 2016	Success
GPS #1 orbit propagator verification	01 Jan 2016	Success
GPS #2 - radio occultation	07 Jan 2016	Success
GPS #3 - radio occultation	08 Mar 2016	Success
Fault tolerant payload	Daily	Automated

Up to current date:
All payload experiments still ongoing

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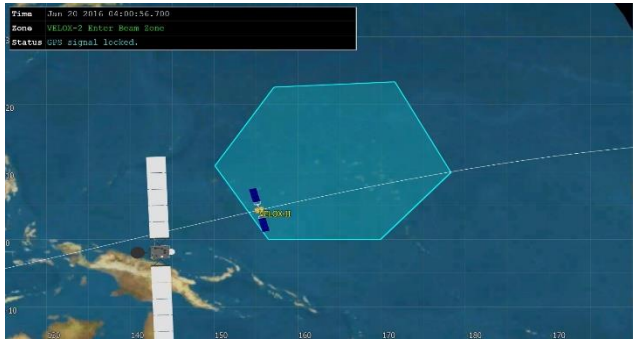
Summary

- VELOX-I
  - Sun-Synchronous Low Earth Orbit (LEO); 4 revisits per day
  - Duration of ground communication per ground pass is approximately 10 minutes
  - Lessons and experience learned
- VELOX-II
  - Near Equatorial Orbit (NEO); 14 revisits per day
  - Requires 24/7 operation; Intensive
  - Higher manpower cost
  - Need for an autonomous ground station
  - Primary payload (IDRS) aids in relaying data through the on demand 2-way inter-satellite communication; More experiments being conducted
  - All experiments have been successfully conducted
- Autonomous Ground Station
  - Setup to cater to VELOX-II requirements
  - In-house developed software updates and frequent routine maintenance imposed to prevent any setbacks



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Future Plans

- VHF/ UHF Ground Station
  - Expose and educate students to real time ground operations; First hand experience on satellite communication
  - Upgrading; To be able to track constellation of satellites

- Mobile Ground Station
  - For temporary usage during maintenance works
  - Currently in progress (By staff and undergraduates)

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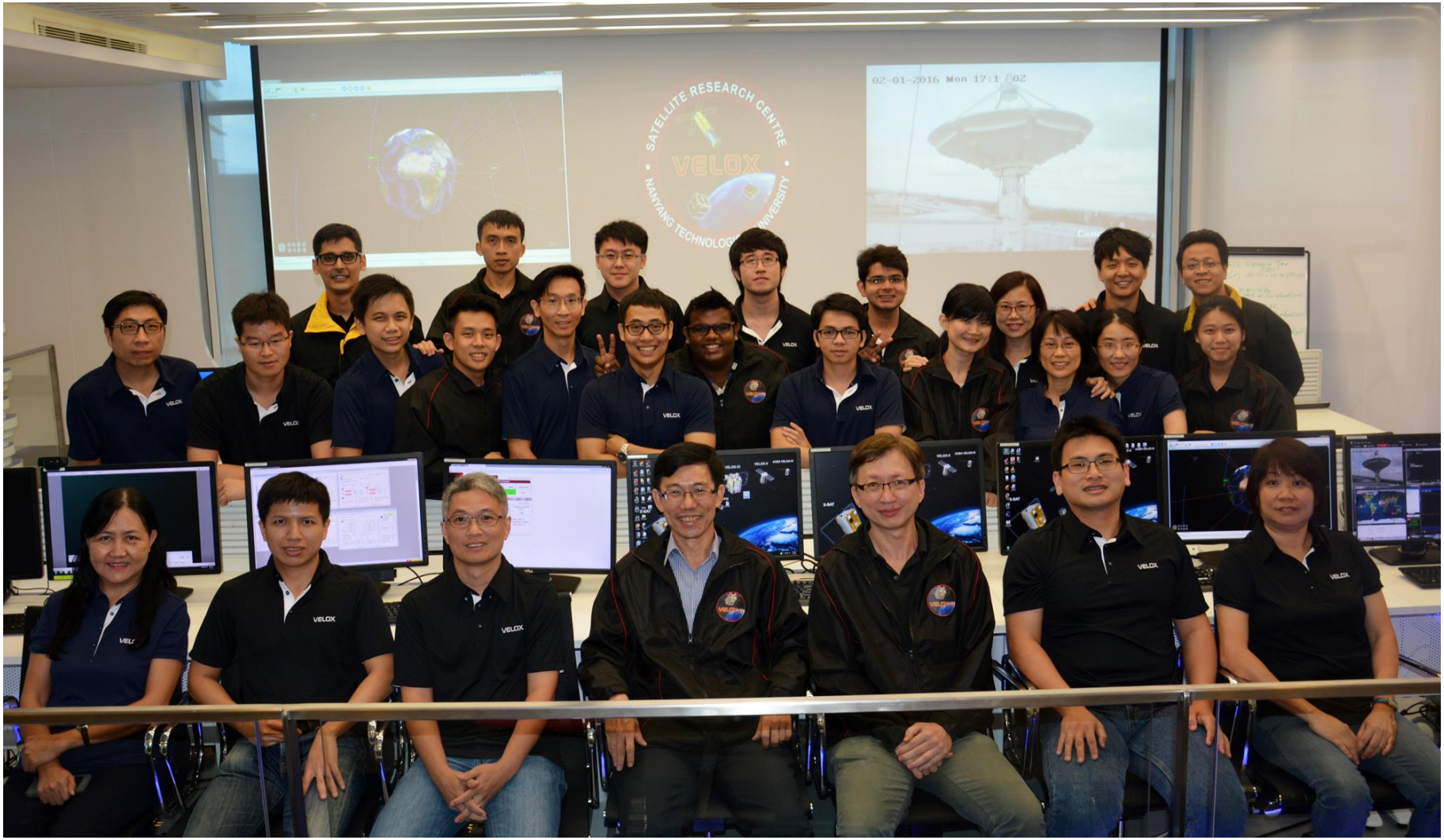
Thank you!



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