Status of MOLI development

MOLI (Multi-footprint Observation Lidar and Imager)

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JAXA

Outline of This Presentation

1. Overview of MOLI
2. Objectives of MOLI
3. Mission requirements and System requirements
4. Element Experiment
5. Observation Area of MOLI
6. Data Products
7. Development Schedule
8. Summary

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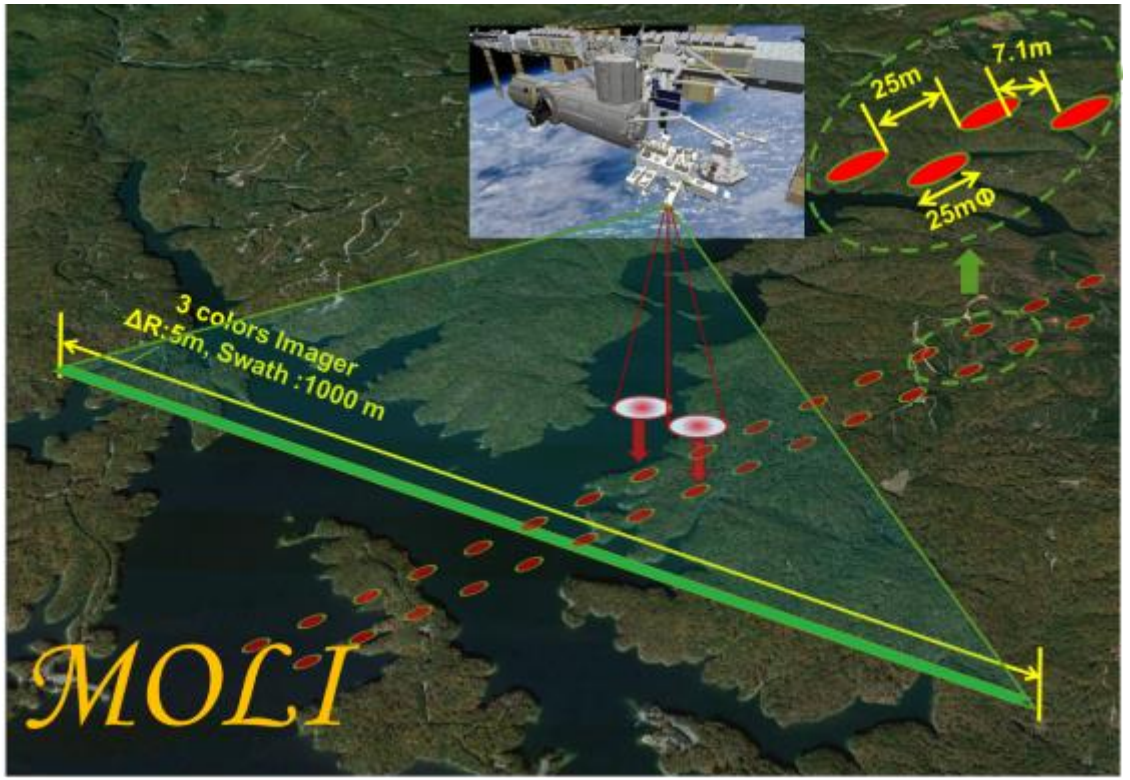
Overview of MOLI

- **MOLI** (**M**ulti-footprint **O**bservation **L**idar and **I**mager)
  - MOLI will be installed on ISS, Mass: 300kg, Power: 400W(TBD)
  - Orbit : ISS orbit
    - Non-synchronous
    - Inclination : 51.6 deg
      Altitude : 330～440 km
- **Sensors**
  - ➢LIDAR
  - ➢Imager



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Objectives of MOLI

- To develop the methods to estimate forest biomass precisely using MOLI data and L-band SAR data, GCOM-C/SGLI data

  MOLI data is set at G-portal. G-portal is a free service providing data of spaceborne sensors that Japan Aerospace Exploration Agency (JAXA) has developed.

- To acquire a spaceborne LIDAR technology to realize the future spaceborne LIDAR such as satellite-borne vegetation LIDAR, three-dimensional laser scanner(LADAR), a doppler LIDAR

Background of Objectives

Global anthropogenic CO_2 budget (IPCC 2013, AR5)

	1750–2011 Cumulative PgC	1980–1989 PgC yr^{-1}	1990–1999 PgC yr^{-1}	2000–2009 PgC yr^{-1}	2002–2011 PgC yr^{-1}
Atmospheric increase[a]	240 ± 10[f]	3.4 ± 0.2	3.1 ± 0.2	4.0 ± 0.2	4.3 ± 0.2
Fossil fuel combustion and cement production[b]	375 ± 30[f]	5.5 ± 0.4	6.4 ± 0.5	7.8 ± 0.6	8.3 ± 0.7
Ocean-to-atmosphere flux[c]	−155 ± 30[f]	−2.0 ± 0.7	−2.2 ± 0.7	−2.3 ± 0.7	−2.4 ± 0.7
Land-to-atmosphere flux	30 ± 45[f]	−0.1 ± 0.8	−1.1 ± 0.9	−1.5 ± 0.9	−1.6 ± 1.0
Partitioned as follows					
Net land use change[d]	180 ± 80[f,g]	1.4 ± 0.8	1.5 ± 0.8	1.1 ± 0.8	0.9 ± 0.8
Residual land sink[e]	−160 ± 90[f]	−1.5 ± 1.1	−2.6 ± 1.2	−2.6 ± 1.2	−2.5 ± 1.3

Terrestrial carbon budget due to land use change and carbon absorption by forests is more uncertain than others. It is important to estimate forest biomass precisely.

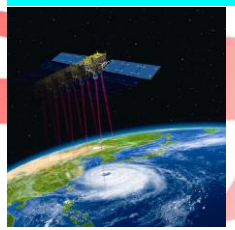
Background of Objectives

MOLI

(2019)

Pressurized laser canister
High peak current/voltage supply
High precise laser pointing

Advanced lidar system



Satellite-borne vegetation LIDAR

3D Laser profiler (land surface)

Doppler LIDAR (wind)

Stable injection seeding
Absolute wavelength control
Double pulse technique
High sensitive SWIR photon-counting
Parametric wavelength conversion

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Mission requirements

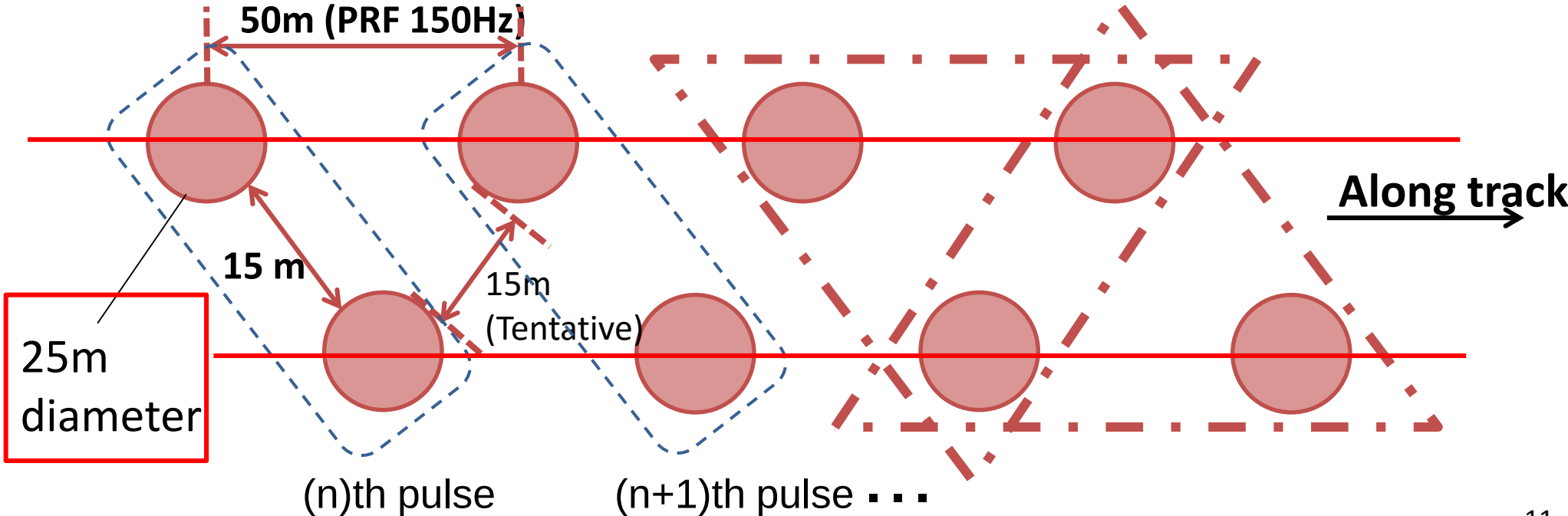
- Canopy Height
  - ±3m(Canopy Height is under 15m)
  - ±25% (Canopy Height is over 15m)
- Biomass
  - ±20t/ha (Biomass density is under 100t/ha)
  - ±25% (Biomass density is over 100t/ha)
- To get information on status of forest, vegetational parameters (phenology) and so on and to classify forest
- Footprint Position Accuracy
  - under ±15m

System Requirements and System Study

Mission Requirements	System Requirements	How to realize
To measure an accurate canopy height (±3 m or ±25%)	LIDAR SNR ≧10	Laser energy is set to 20mJ Receiver diameter is set to 0.45m. High responsibility detector APD is used.
	Footprint diameter : 25m	Beam divergence expands to 62.5 μrad by beam expander.
	Terrain Relief Correction Sampling Design: 2 lines along track 150Hz pulse repetition frequency	The number of beam is set to 2. Laser Pulse Repetition Frequency (PRF) is set to 150Hz. Beams are separated from 1 LASER.
To understand lidar footprint location and vegetational parameters	Imager with 5.0m Spatial resolution (GSD) 1km swath 3 bands (Green, Red, NIR)	MOLI will use a customized imager.
Footprint Position Accuracy ≦±15m	System to determine the laser direction under 37.5 μrad	MOLI will have STT and GPS and so on.

Sampling design and footprint diameter

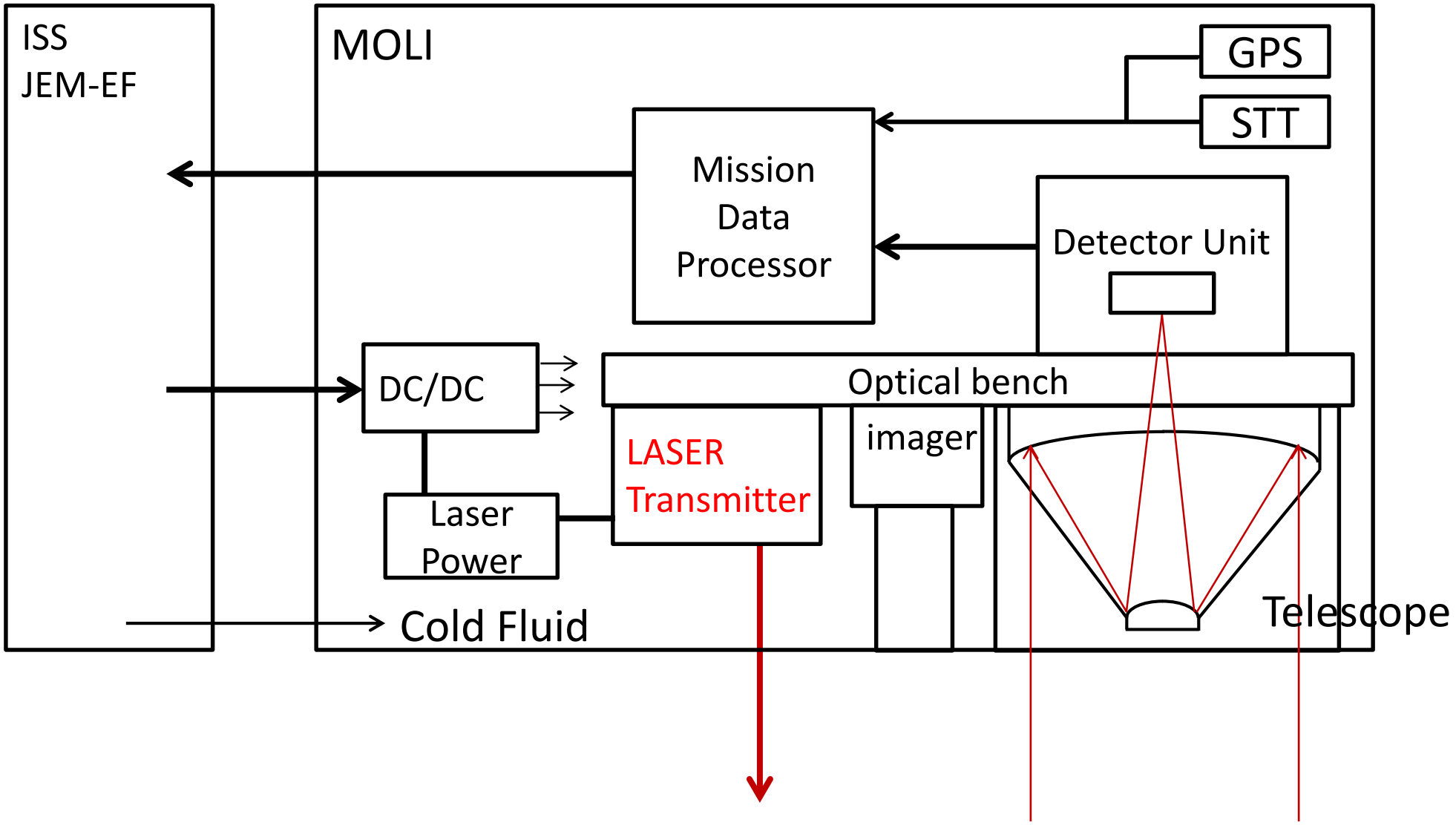
- **To detect a top point of canopy**
  - We set the diameter of footprint to be 25 m.
- **To get a number of sample**
  - A number of sample is needed for measuring accurate biomass.
  - MOLI samples 2 lines along track.
    (MOLI creates 2 footprints by transmitting 2 laser beams.)
- **To estimate a slope angle of ground surface**
  - MOLI can estimate a slope angle of the ground surface using 3 footprints.



Main Specifications

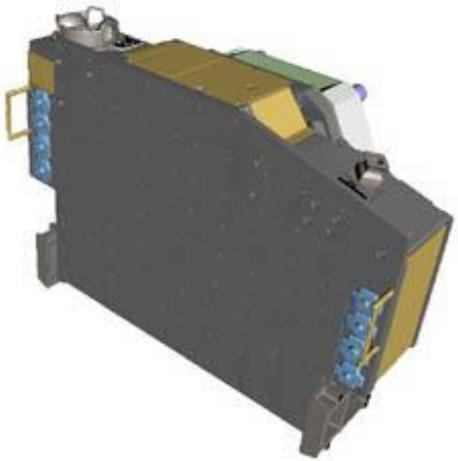
Item	Value	Notes
Laser Wavelength	1064 nm	Nd:YAG Laser
Laser Energy	20 mJ	
Number of Laser	2	
Pulse Repetition Frequency	150 Hz	
Laser Beam Divergence	62.5 µrad	
Diameter of Telescope	0.45 m	
Diameter of one receiver footprint	25 m	
Number of receiver element	2	array detector
Observation range	-50 m ～ 150 m	
Imager resolution	5.0m	
Bands of Imager	3(Green, Red, NIR)	
S/N of Imager	over 50	

Schematic Diagram of MOLI System



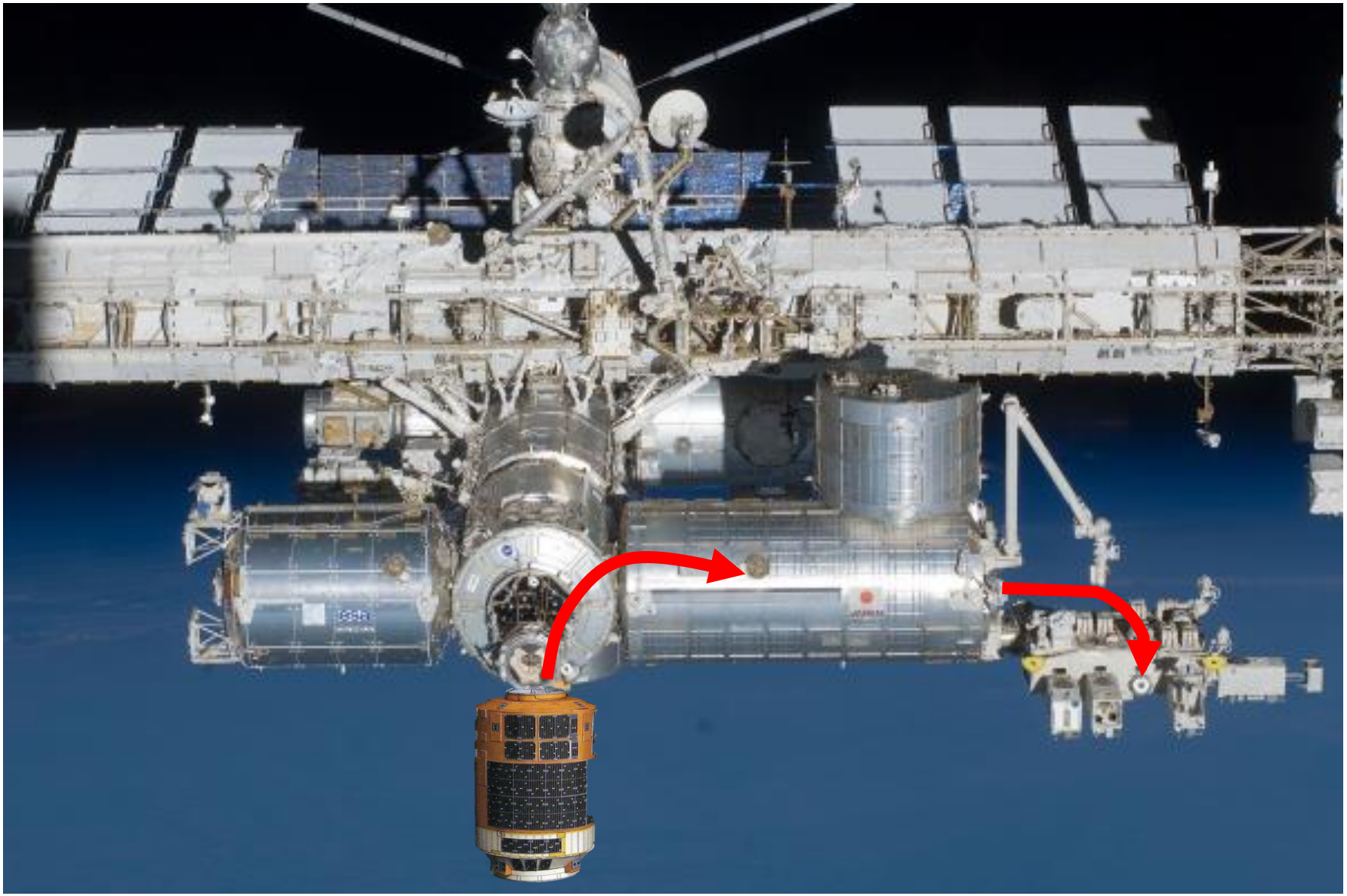
Outline of i-SEEP

MOLI will be installed on ISS using improved i-SEEP.
An i-SEEP stands for IVA-replaceable Small Exposed Experiment Platform



Packing

Outline of i-SEEP



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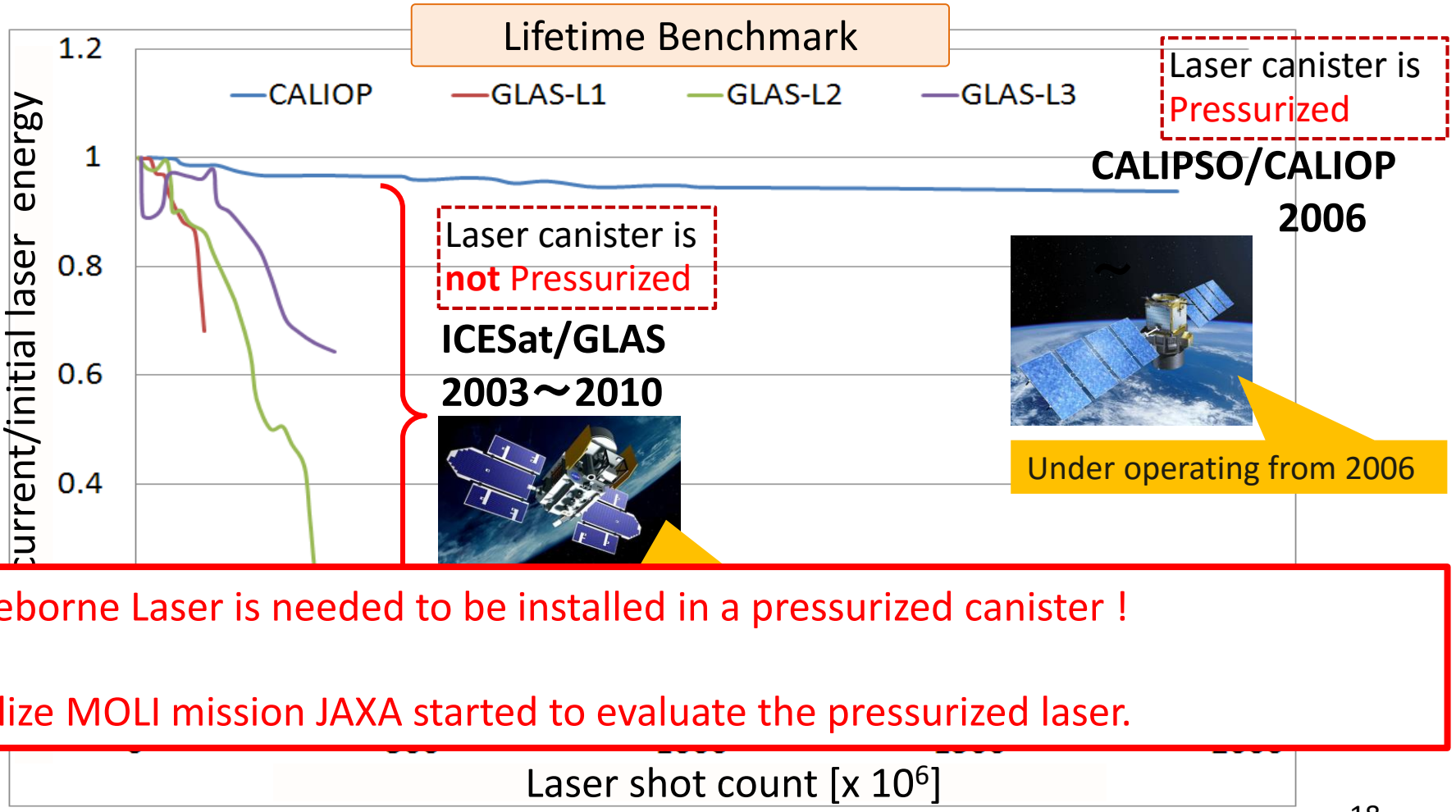
Trial test of Laser transmitter

Problem on the laser induced contamination (LIC)

The LIC is one of the major issue to realize a space borne lidar.

The LIC reduces a damage threshold of the optical coatings, which results in limitation of the laser lifetime in space environment.



→ Spaceborne Laser is needed to be installed in a pressurized canister !

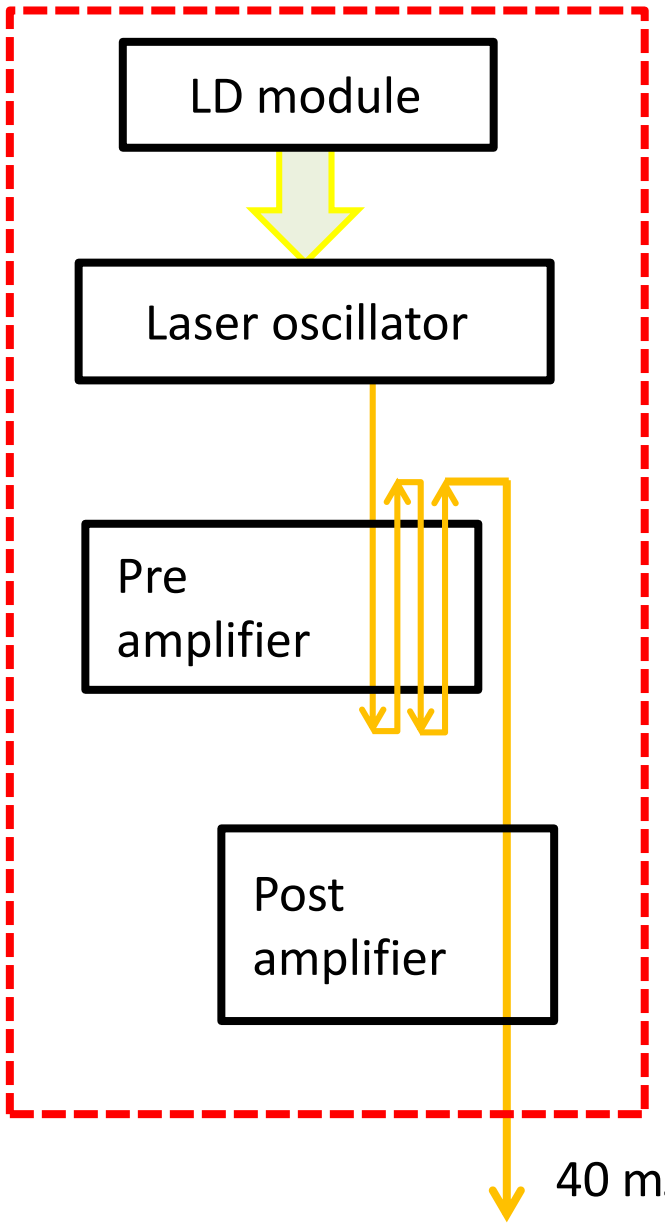
To realize MOLI mission JAXA started to evaluate the pressurized laser.

Required Parameters for MOLI Laser

Item	Value	Note	Specifications of a Test model Laser
Laser energy	20mJ / 1 pulse (40mJ / 1 pulse is separated to 2 beams)	To achieve required SNR (≧10)	40mJ
Laser PRF	150Hz	To get required number of samples	150Hz
Pointing stability	< 100 μrad	To determine the geolocation of a laser footprint	
Laser-incuded contamination	Laser canister is Pressurized around 1 atm	To avoid LIC	Laser canister is Pressurized around 1 atm
Life	Over 1 year		

6W laser

Schematic Diagram of test model Laser transmitter

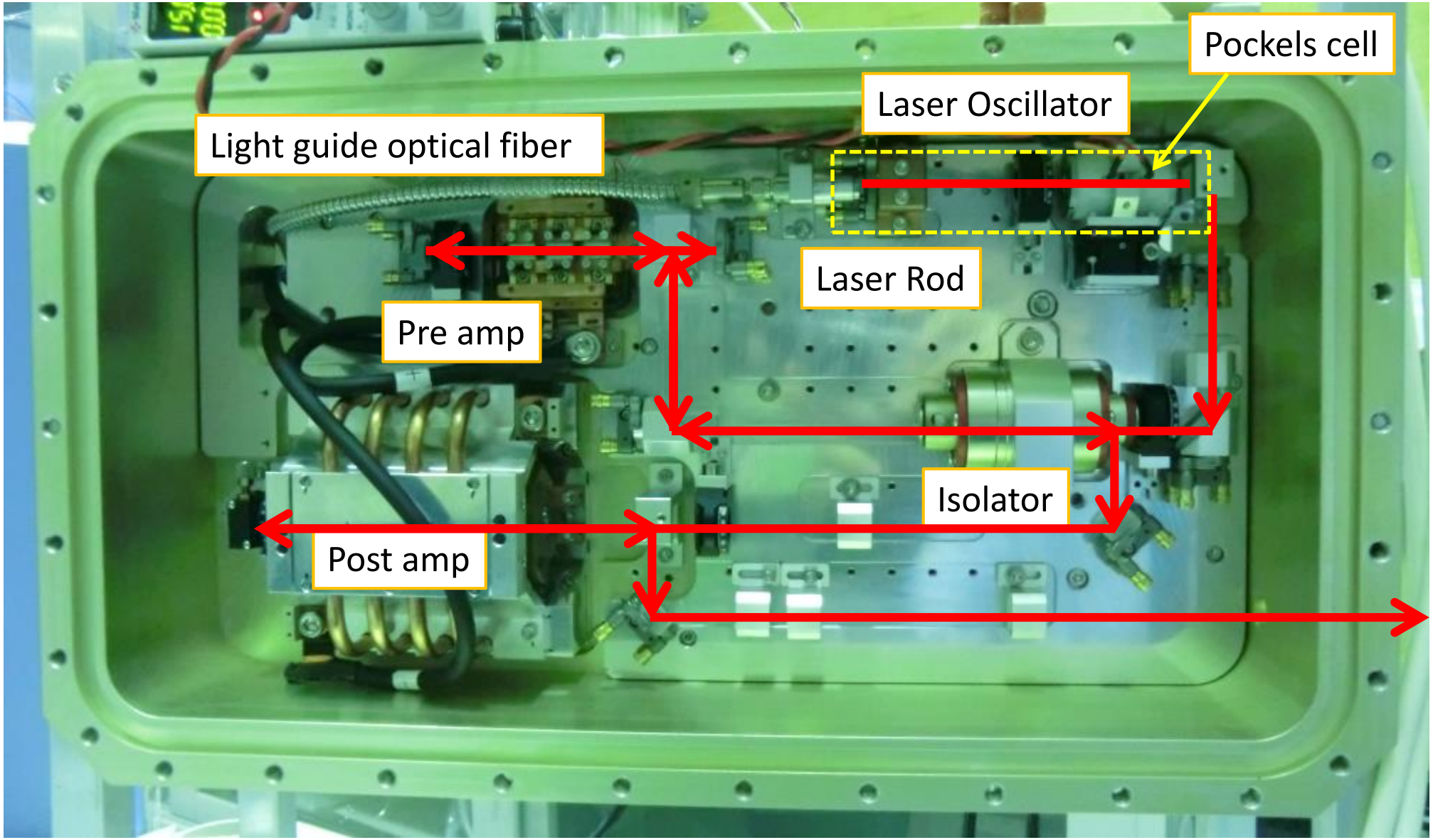


Pressurized canister

Oscillator
2 mJ, 150 Hz Output

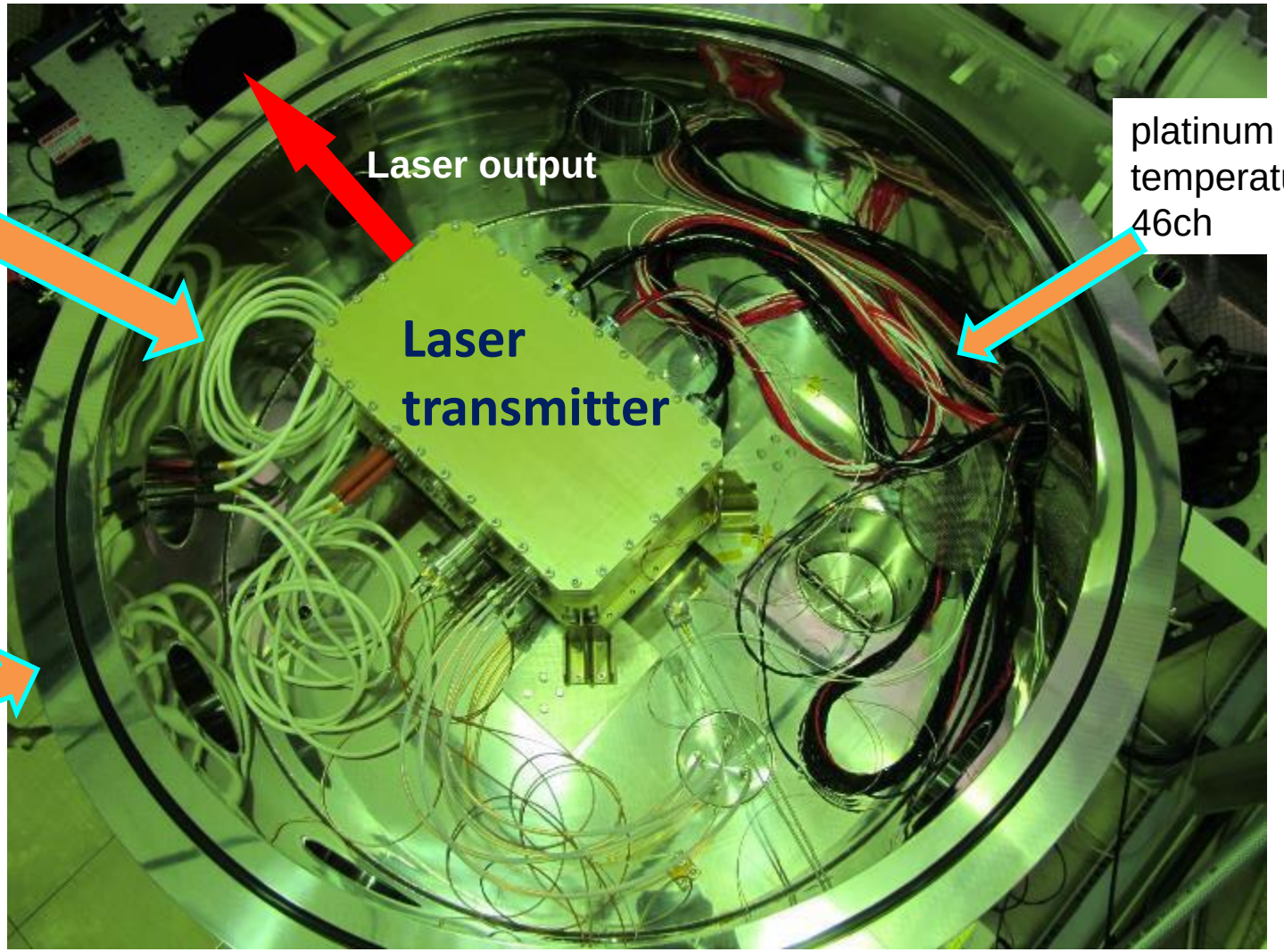
Pre Amp
Double Pass
12 mJ, 150 Hz Output

Test model Laser transmitter



Setup in vacuum chamber

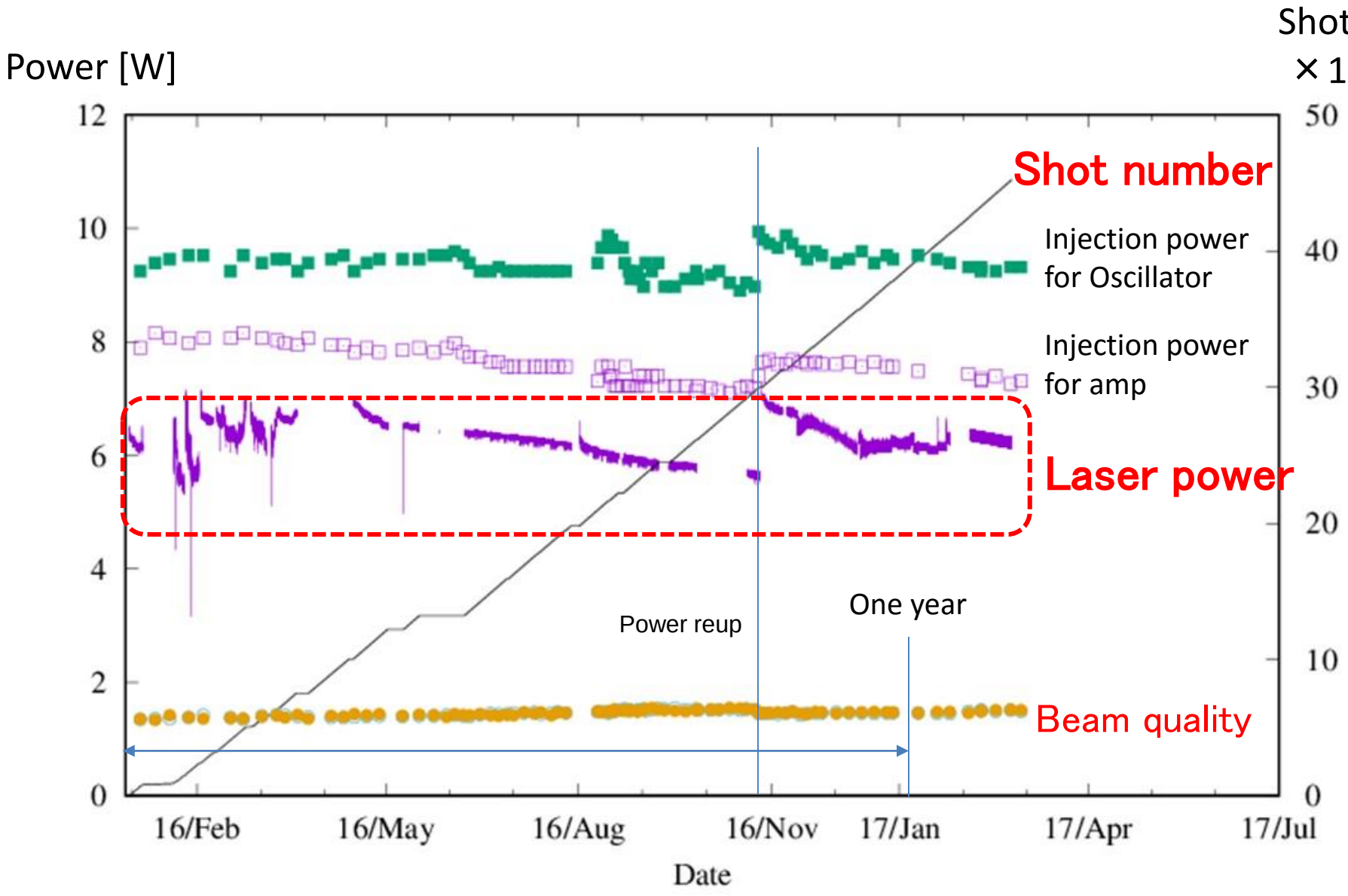
Current In/Out for Oscillator and Amplifier



platinum resistance temperature sensor 46ch

ϕ1m vacuum chamber

Current result of trial test of Laser



trial test result summary

Item	Spec	test Result	status
wavelength	1064nm	1064nm	confirmed
Laser energy	40mJ / 1pulse	40.7mJ / 1pulse	confirmed
Laser PRF	150 Hz	150 Hz	confirmed
Pointing stability	< 100 µrad	< 10 µrad	confirmed
Pressurized	About 1 atm.	About 1 atm.	confirmed
Life	1 year (target)	1.5 year	confirmed

Airborne Lidar Experiment

We have conducted Airborne Lidar Experiment. We have good results.
Details are explained in Mr. Mitsuhashi's presentation.

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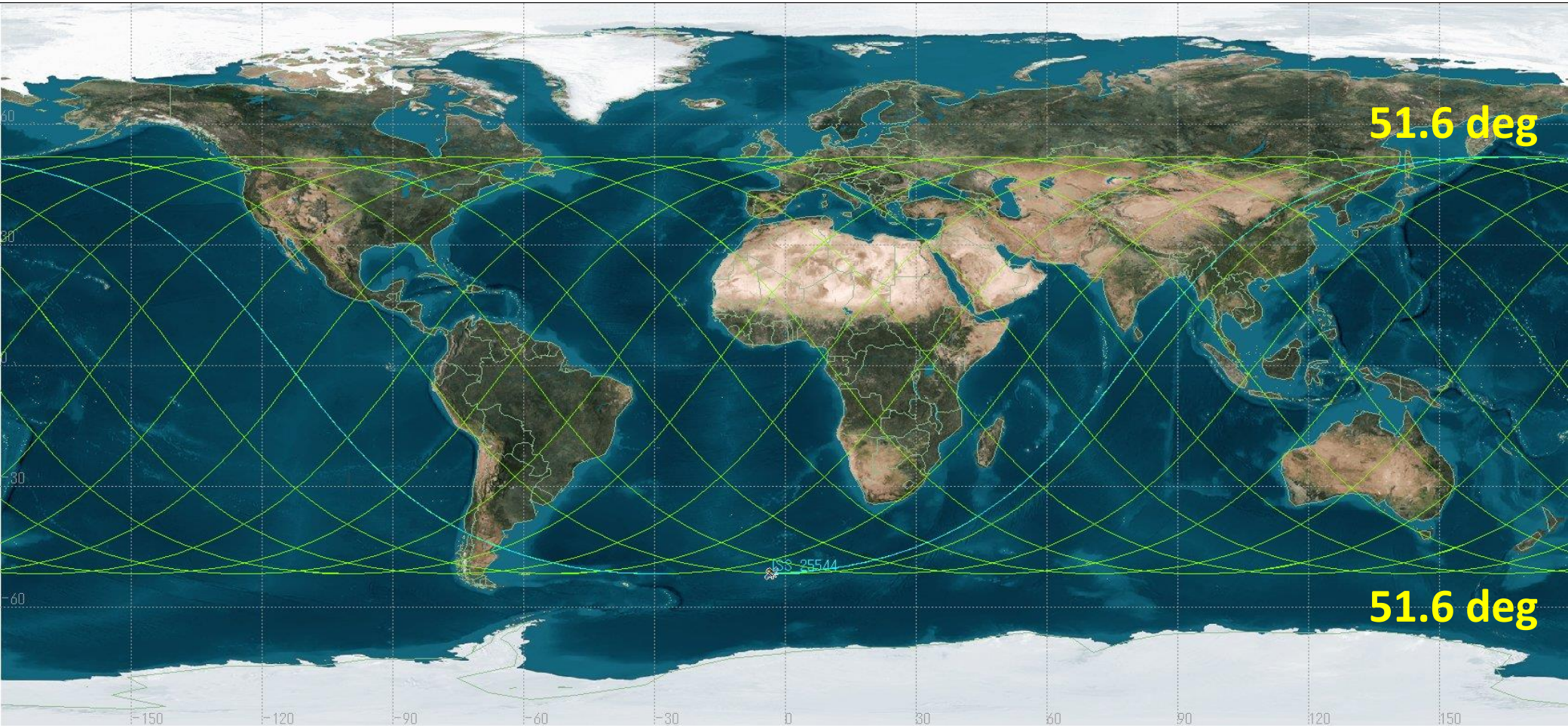
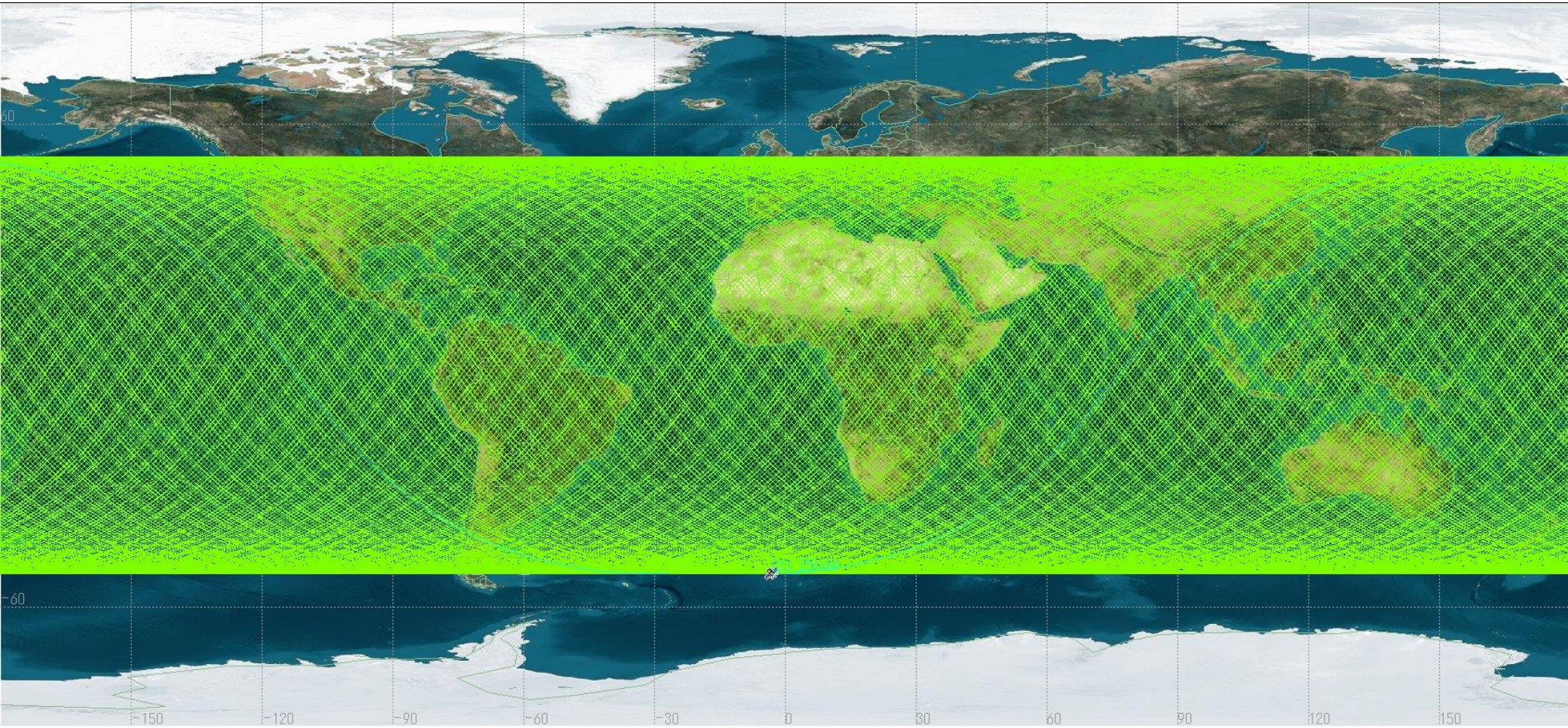
MOLI observation area : one day for global

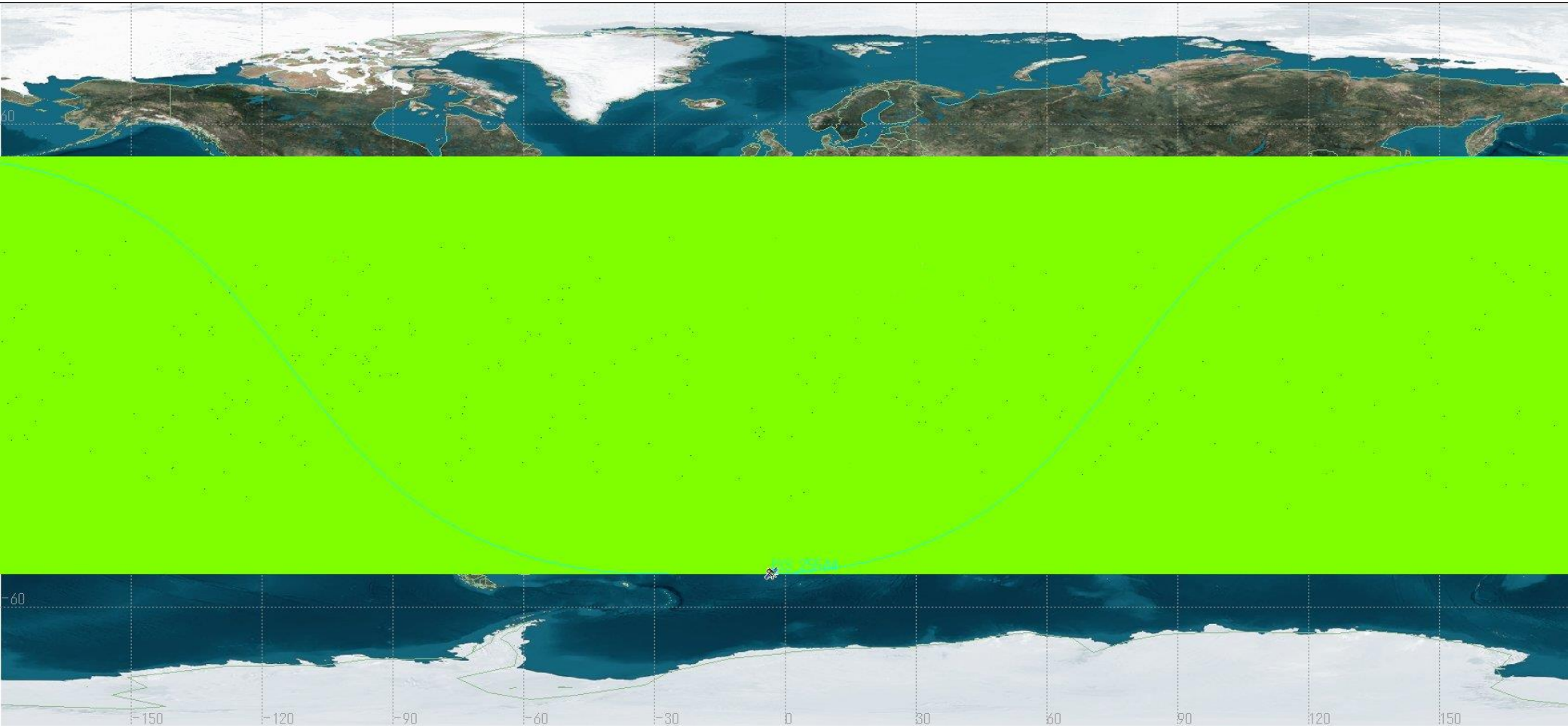


The inclination of ISS orbit is 51.6 deg.

MOLI observation area : one month for global



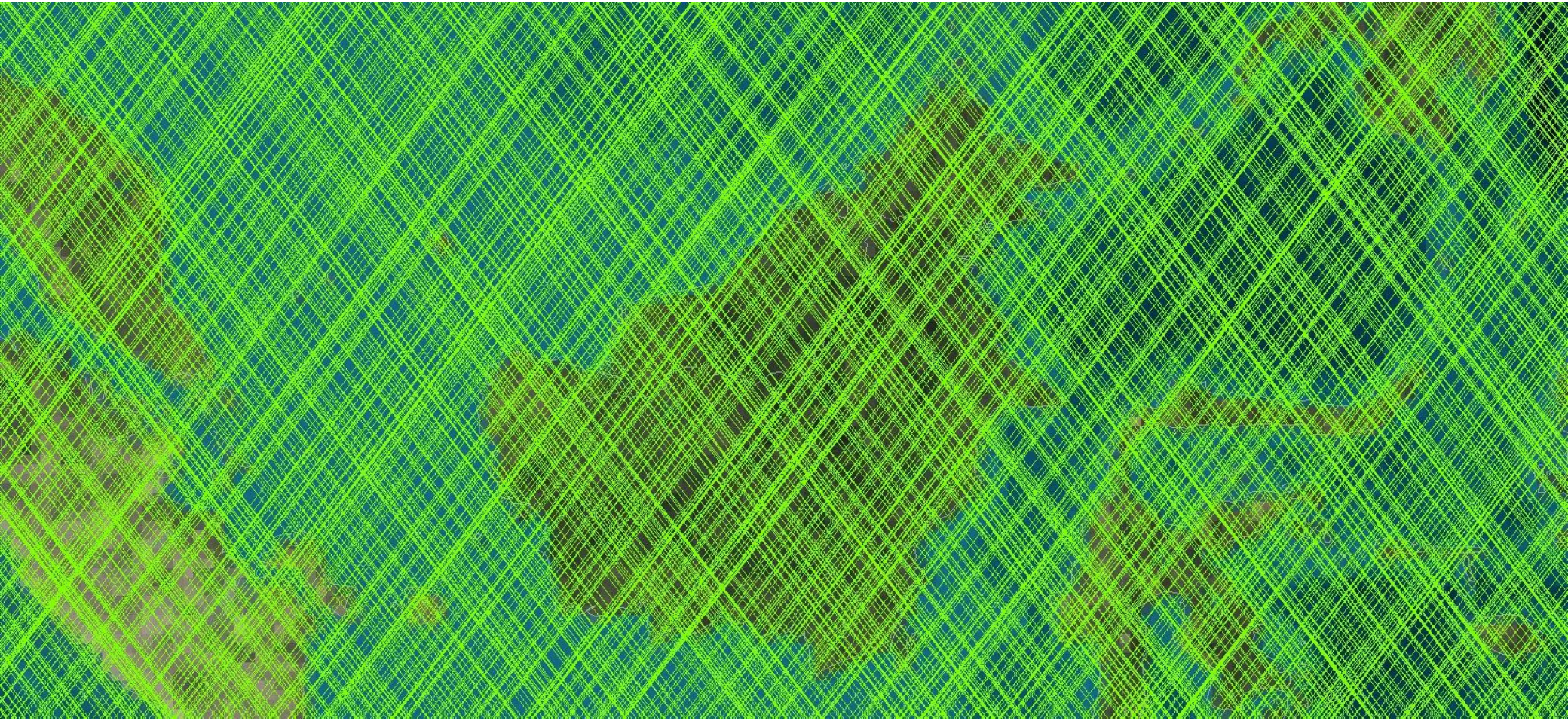
MOLI observation area : one year for global



MOLI observation area : one day for particular area Borneo

MOLI observation area : one month for Borneo

MOLI observation area : one year for Borneo



The gap between the orbit is 3.5 km on the average.

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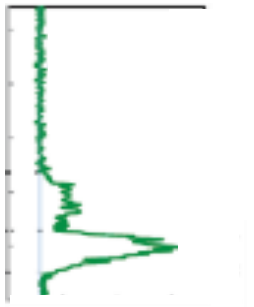
Standard products of MOLI (tentative)

Product level	Product category	Products	Remark
L1	Lidar footprint products	Waveforms	including geolocation data
	Imager product (1km swath)	Image	geometrically corrected
L2	Lidar footprint products	Canopy heights	including geolocation data
		Above Ground Biomass	including geolocation data

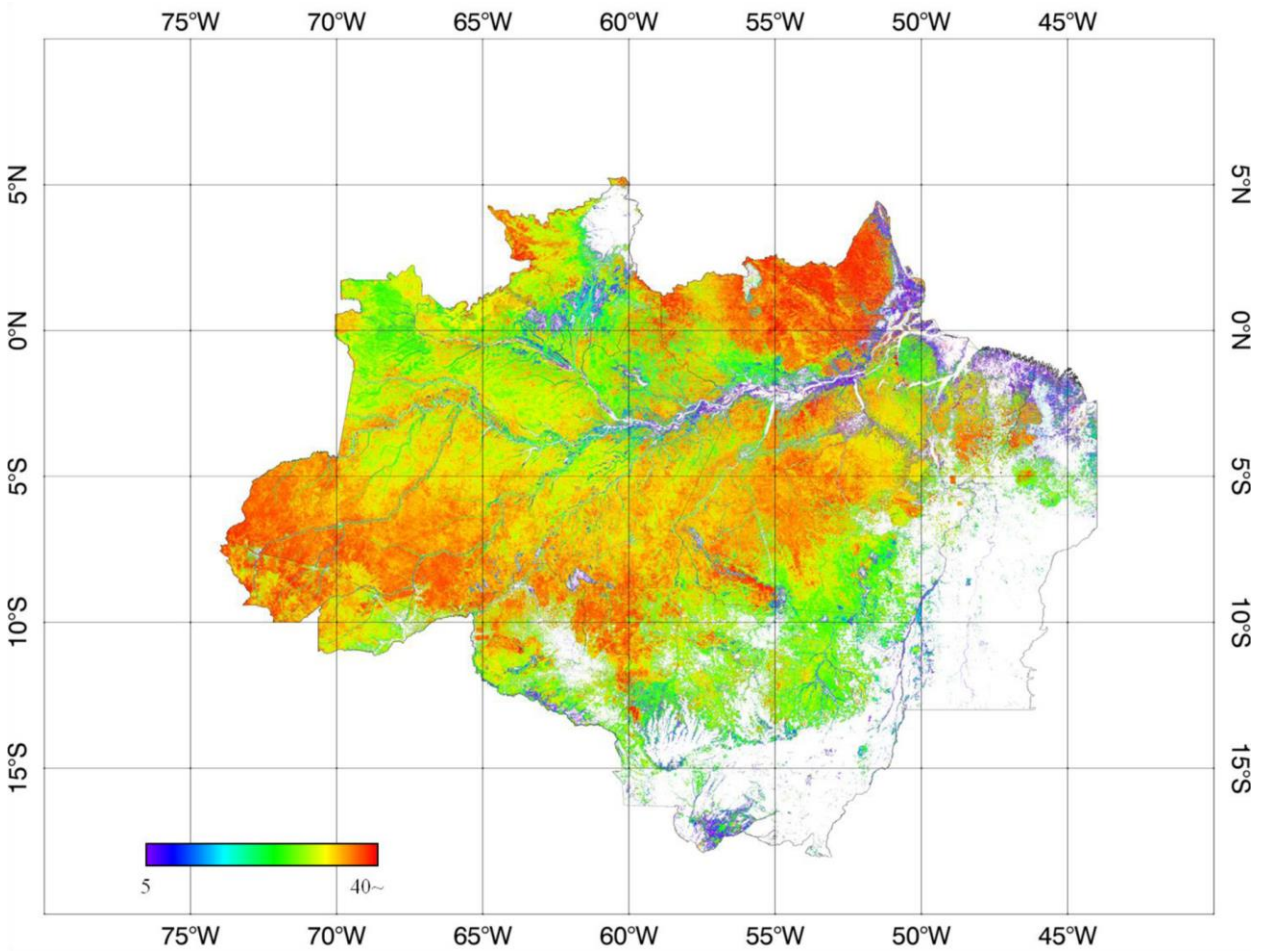


L1 Product: Waveforms

Research products of MOLI (tentative)

Product level	Product category	Products	Remark
L3	Integrated products with Lidar and imager (1km swath)	Tree canopy heights	
		Forest biomass	
L4	Wall-to-Wall map products	Tree canopy height Map	
		Forest biomass map	

Sample Image of L4 products



Y. Sawada et al., 2015
A new 500-m resolution map of canopy height for Amazon forest using spaceborne LiDAR and cloud-free MODIS imagery)

Amazon area forest height map using GLAS and MODIS data
Regarding to MOLI, We make L4 products using MOLI and GCOM-C/SGLI or MOLI and PALSAR-2 data.

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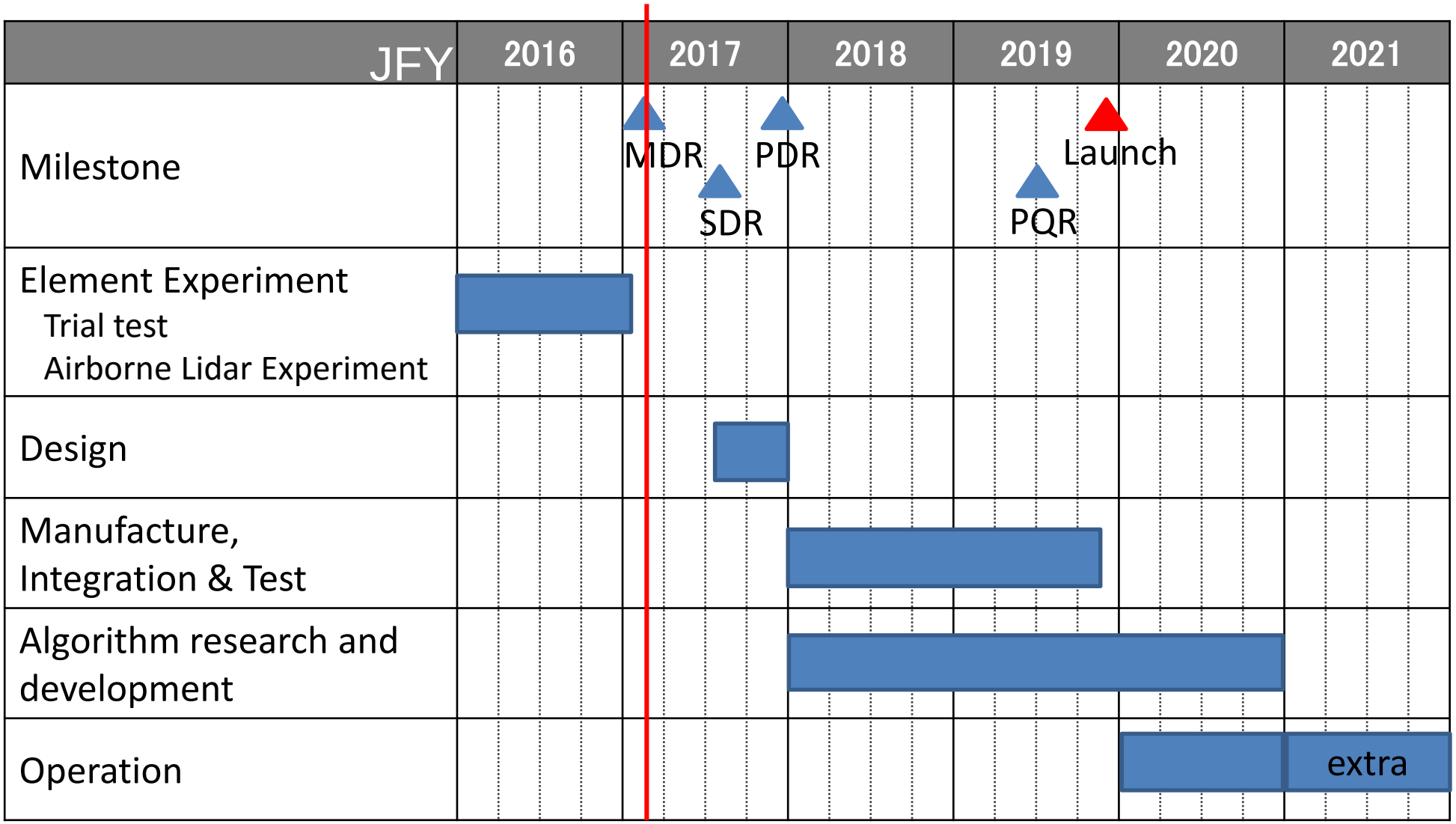
Schedule (tentative)



Mission Definition Review(MDR) is just finished.
Phase A will be started soon.

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Summary

- We define Mission requirements and System requirements.
- We have conducted a trial test of a laser transmitter and airborne lidar experiment and have good results.
- We plan to launch MOLI in 2019.
- MDR is just finished. Phase A will be started soon.