Conceptual Study and Near Future Plan of Space LIDAR

Noritaka TANIOKA , Shigeo ISHII , Atsuo TSUIKI , Yasuji YAMAMOTO

Remote Sensing Technology Laboratory, Office of Research and Development
National Space Development Agency of JAPAN (NASDA)

Introduction

NASDA has been investigated lidar system for five years. From the results of this investigation, we found the way to make the lidar demonstration flight model using the small satellite. Our current status is as follows.

The feasibility study of space lidar system was done in 1991. The trial product of 100mJ high power laser oscillator was done successfully in 1992. The trial product of 30 and 20 cm light weight mirror was done successfully in 1993. The trial product of laser detector using PMT(Photomultiplier Tube) and Si-APD(Avalanche Photo Diode) was done successfully in 1994. The airborne lidar system which is assembled from past trial products is being integrated, and thermal life test of high power oscillator is under going by our contractor in this year.

Now we are considering next step, and NASDA is planning the mie scattering demonstration flight by the H-2 launch vehicle early 2001. This demonstration flight will get the great useful data, and it will show feature of operational lidar satellite. Also NASDA would like to investigate advanced lidar system such as DIAL, altimeter and Doppler LIDAR.

Feasibility Study

In order to identify what kind of lidar system is appropriate for NASDA to pursue in the following years, a comparison with three different types of lidar was done.

(1)Altimeter

High power laser is not required. However, orbital determination certainty

is the most critical point to solve to acquire absolute altitude with high precision.

(2)Atmosphere observation lidar

High power laser is required, and the telescope should be larger (~ 1m ϕ) than that of altimeter. However, the attitude error and orbit determination uncertainty are no problem. So, its feasibility is high.

(3)Differential absorption lidar

Laser power and telescope size are about the same as atmosphere observation lidar. Tuning mechanism to bring the laser wavelength to water vapor absorption band is required and at least two laser beams are necessary. They are under investigation to realize now.

In 1991 , design study was conducted for 2 lider systems, Mie-LIDAR for aerosol observation, and DIAL for water vapor measurement.

Mie-LIDAR was thought to be feasible as a spaceborne system with the completion of design study in 1991, the next logical step was thought to be experimental manufacturing of some key components.

Trial products

In 1992, two systems constructed, one by NEC and another by MITSUBISHI. As was stated earlier, these systems are for experimental manufacturing of space hardware, as well as for experiment of lidar observation from aircraft.

By march 1993, laser parts were constructed.

YAG system used two Nd:YAG rods, each radially illuminated by 8 laser diodes from 8 different angles. YLF system used single c-axis-pulled Nd:YLF rod pumped by laser diodes from 16 different angles.

The YAG system employed heat conductive metal sleeve, while the YLF system used ethylene glycol water as cooling medium of rods.

Both system used Pockels cell as Q switch mechanism and KTP crystal for SHG.

By march 1994, the receiving mirror were constructed. Two systems constructed, one by MITSUBISHI and another by TOSHIBA.

By march 1995, the detectors were constructed. Optical detector is key

component for the spaceborne. Especially, Si-APD detector was improved on concerning large scale active area(ϕ =500 μ m) and high countrate.

Test data of both systems are summarized in Table 1.

Table 1 Summary Measured Performance

Laser		YAG system	YLF system
	Wavelength	1064nm&532nm	1053nm&527nm
	Output Power	104mJ(50Hz)	109mJ(50Hz)
	P.R.F	20～50Hz (Adjustable by 5Hz)	
	OutputStabilityOverTime	< 30%(45,000shots)	< 10%(50,000shots)
	Beam Spread Angle	0.5mrad	0.8mrad
	Laser Output/LD Input	7%	7～8%
Telescope			
	Aperture	300mm ϕ	200mm ϕ
	Primary Mirror Material	foamed quartz	beryllium
	Overall Transmittance	32%(1064nm)	35%(1053nm)
	Receiver Field of View	0.5mrad	< 1.25mrad
	Filter Bandwidth	2nm	0.8nm
Detector		Si-APD	PMT
	PhtonDetectionProbability /QuantumEfficiency	39%(532nm) 2%(1064nm)	9%(527nm) 0.03%(1053nm)

System Design

System study of spaceborne lidar is under going as the Mie-LIDAR with considering current technology.

It will be realized in the near future that the space lidar (with a mass of less than 250 Kg and electric power consumption of less than 250 W) be used for 3-dimensinal global mapping of clouds and enhanced aerosol layers.

The system parameters of the Mie-LIDAR are shown in Table 2.

Table 2 System Paremeters of Mie-LIDAR (Preliminary)

Altitude	500Km
Wavelength	1064/532 or 1053/527 nm
Output Power	TBD
Pulse Repetition Frequency	10～100 pps(TBD)
Beam Spread Angle	0.32mrad.(TBD)
Effective Aperture	TBD
Receiver Field of View	0.32mrad.(TBD)
Filter Bandwidth	0.1nm
Hor.Spatial Resolution	< 1.5Km
Ver.Spatial Resolution	< 100m
Observation Range	0～40Km

Conclusion

Now YAG system is assembling the existing hardware to test on the ground. The purpose is to test the functionality of the hardware, for example, thermal life test of high power osillator. After that, it will be further utilized to complete the ground-based lidar. YLF system is assembling for the airborne lidar.

Spaceborne system will be planned in visible future. There is a lot of work, both managerial and technical. We need experiments of ground-based lidar and that of airborne lidar.

We would like to express our thanks to the advice of many researchers from institutes and universities.

Conceptual Study and Near Future Plan of Space LIDAR

N. TANIOKA S. ISHII A. TSUIKI Y. YAMAMOTO

Remote Sensing Technology Lab.
Office of R&D, NASDA

Vision

- Spaceborne LIDAR has potential to make significant contribution to meteorological and climatological researches.
- NASDA will contribute to some part of global observation system.
- NASDA will launch Mie Scattering LIDAR in 2001. (demonstration satellite)
- NASDA will research into DIAL, Altimeter and Doppler LIDAR.

Implementation Plan

■ STEP 1 System Study (Pre-phase A)
- Investigation of Mie Scattering LIDAR.
- Identification of critical devices and technologies.

■ STEP 2 System Analysis (phase A)
- Preliminary design and analysis. 1991～
- Trial products of critical devices. 1992-94
- Evaluation of critical device's characteristic. 1994～

Implementation Plan (cont.)

■ STEP 3 Airborne LIDAR Flight Test(phase A)
- Assembly of airborne LIDAR. 1995
- Acquisition of flight test data. 1996
- Analysis of flight test data. 1996
- Evaluation of Availability. 1996

■ STEP 4 MS-LIDAR demonstration satellite (phase B)
- NASDA is requiring the budget. 1995
- Start the MS-LIDAR development. 1996/04

Implementation Plan (cont.)

- STEP 5 System study of operational LIDAR
  - Start system study of operational spaceborne LIDAR.
- STEP 6 Launching of MS-LIDAR satellite
  - MS-LIDAR will be launched in Feb. 2001.
- STEP 7 Development of Operational LIDAR
  - MS-LIDAR will conduct operational spaceborne LIDAR.

Current Status (1/2)

- Trial Product of critical devices done in 1992-94.
  - Diode Oscillator 100mJ(Nd:YAG & Nd:YLF)
  - Telescope
    - » 20cm(beryllium), 30cm(foamed quartz)
  - Detector
    - » Photomultiplier Tube(PMT)
    - » Si Avalanche Photo Diode(Si-APD)
- Investigation of MS-LIDAR is under going. (system parameters, weight, E-power etc.)

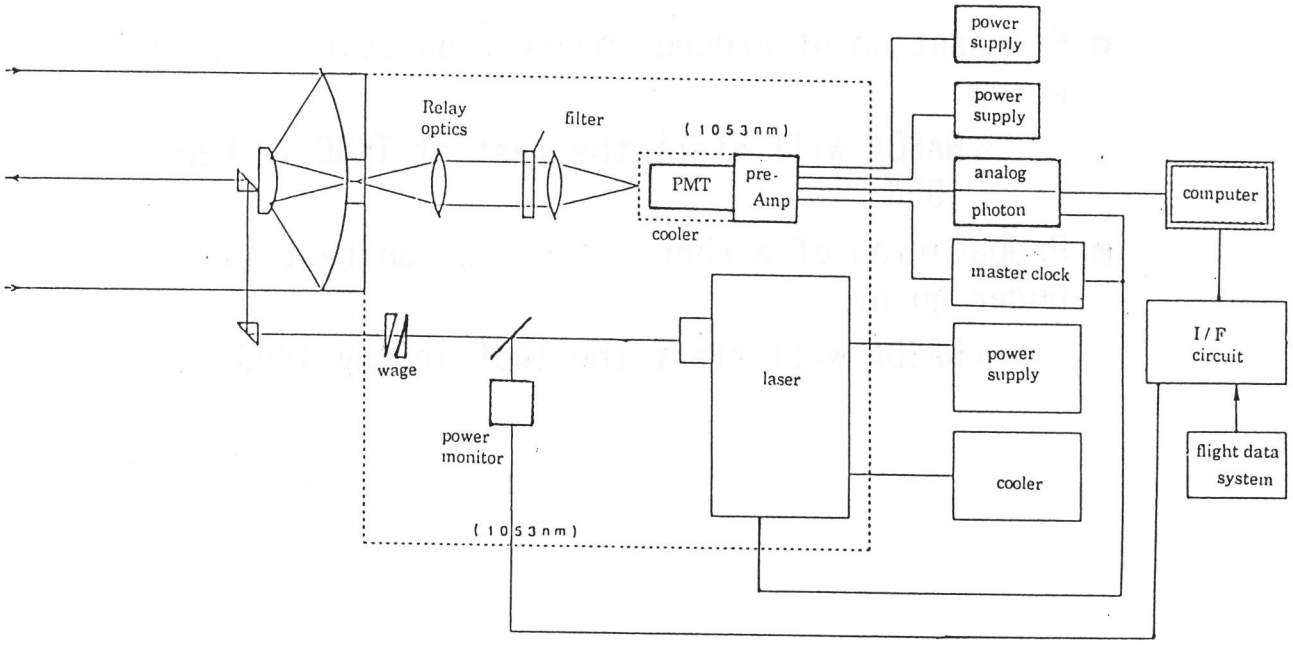
Current Status (2/2)

- Preparation of ground observation test is under going.
  - » NASDA will start the test at TKSC in Feb. 1996.
- Preparation of airborne observation test is under going.
  - » NASDA will start the test in Aug. 1996.

Airborne LIDAR Test Plan

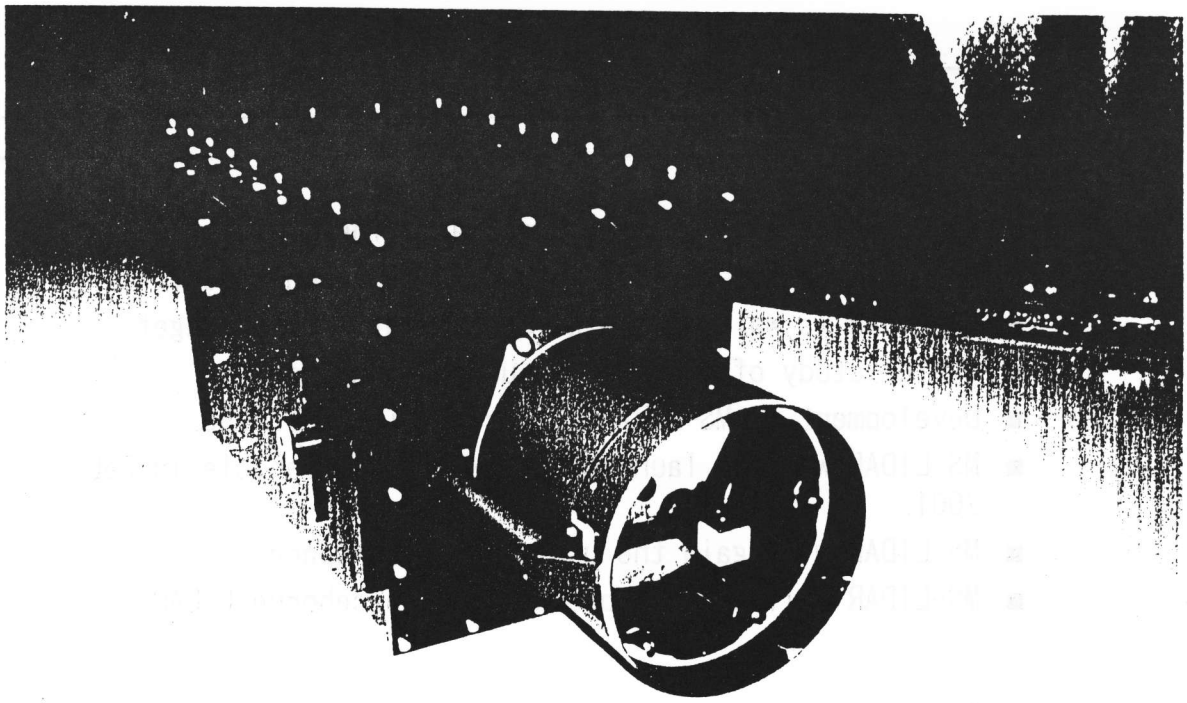
- Assembly of airborne LIDAR is under going.
- Preparation of test plan is under going.
- 1st. test of airborne LIDAR will be done in Aug. - Sep. 1996.
- 2nd. test of airborne LIDAR will be done in Apr. - May 1997.
- Asembly of airborne DIAL will be done in 1997.
- Airborne DIAL will be tested in 1998.

Airborne LIDAR Configuration



Specification for Airborne LIDAR

Target to measure	aerosol, cloud
Spatial Resolution	75m(vertical), 1km(horizontal)
Wavelength	Nd:YLF 1053nm
Output Power	1.75mJ/pulse eye-safe level based on JIS standard
Pulse Repetition Frequency	20Hz - 50Hz (adjustable by 5Hz)
Beam Spread Angle	0.8mrad
Telescope Aperture	0.2m ϕ
Receiver Field of View Angle	0.8-1.25mrad
Filter Bandwidth	0.8nm
Detector	Photo Multiplier Tube
Quantum efficiency	0.03%



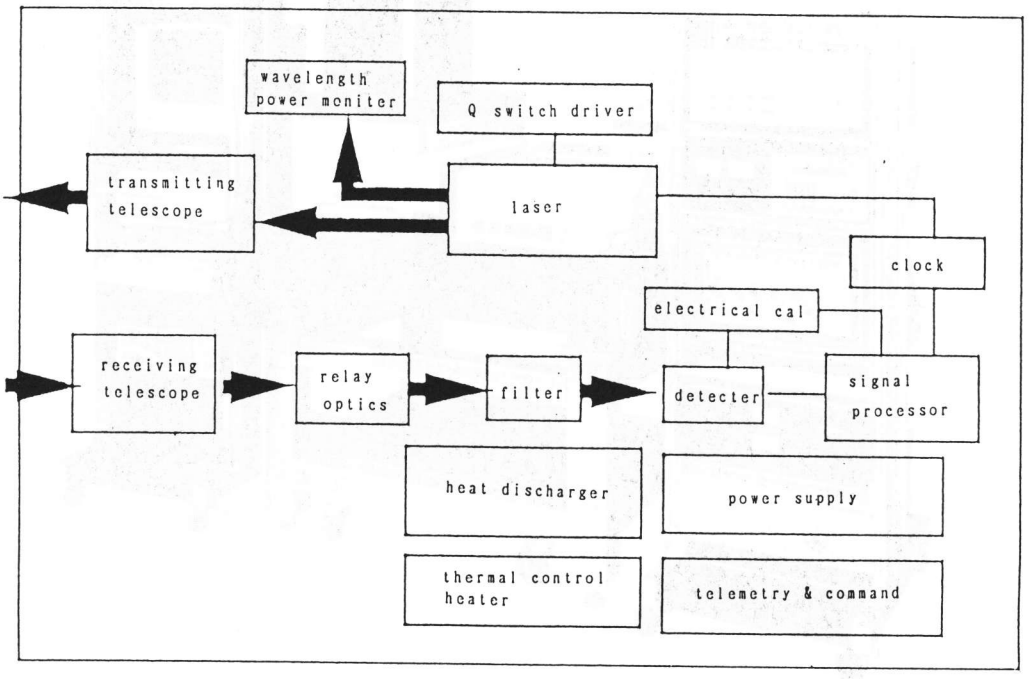
LIDAR FOR AIRBORNE TEST

LIDAR FOR GROUND TEST

MS-LIDAR Demonstration Satellite

- MS-LIDAR is experimental Mie Scattering LIDAR.
- MS-LIDAR is categorized into demonstration satellite.
- MS-LIDAR is waiting the allocation of 1996's budget.
- System study of MS-LIDAR is under going now.
- Development of MS-LIDAR will start in Apr. 1996.
- MS-LIDAR will be launched by H-2 launch vehicle in Feb. 2001.
- MS-LIDAR will gain the useful data in space.
- MS-LIDAR will conduct operational spaceborne LIDARs.

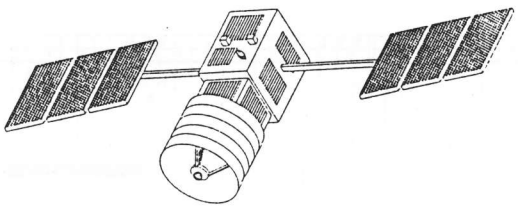
MS-LIDAR Configuration

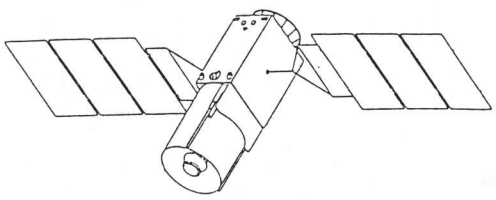


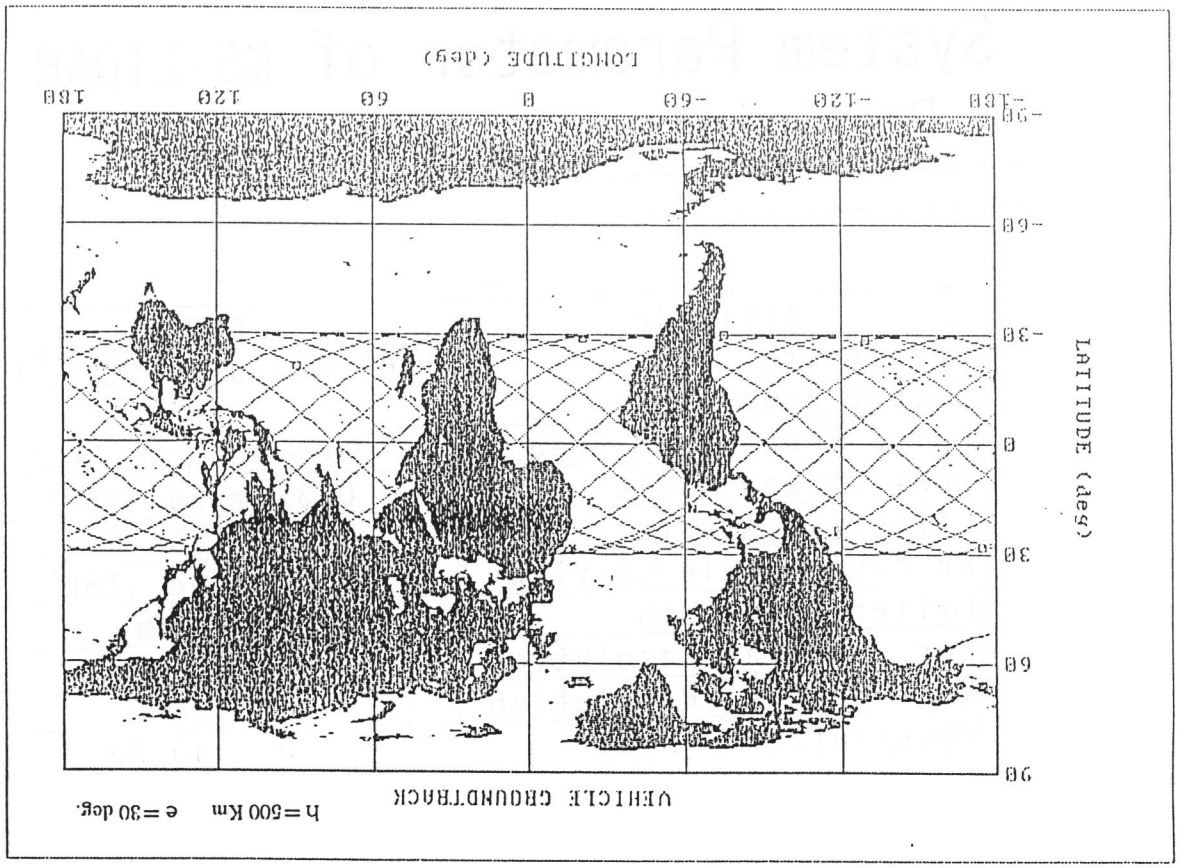
System Parameter of MS-LIDAR
(Preliminary)

Altitude	500km
Wavelength	1064/532 or 1053/527 nm
Output Power	TBD
Pulse Repetition Freq.	10 -100 pps(TBD)
Beam Spread Angle	0.32 mrad.(TBD)
Effective Aperture	TBD
Receiver Field of View	0.32 mrad.(TBD)
Filter Bandwidth	0.1 nm
Hor. Spatial Resolution	$<$1.5 Km
Ver. Spatial Resolution	$<$100 m
Observation Range	0 - 40 Km

Candidates of Satellite Configuration for MS-LIDAR







MS-LIDAR Schedule (Preliminary)