Ocular Hazard Probability of MDS-LIDAR

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NASDA has a project to launch a LIDAR mission satellite named MDS (Mission Demonstration Satellite) in 2001. Before making the final decision to go ahead, it is necessary to investigate the safety of the system for human ocular organ. NASDA is now conducting the investigation through a Committee in Japan Space Forum. The Committee consists of themembersfromfields in the earth observation, the astronomical observation, the laser technology, the ophthalmology, and the mathematics. Various aspects of the problem were inquired. Here, I will report parts of the investigation with focussing on the hazard probability analysis.

The policy of study on ocular hazard probability is as follows:

1)Consider LIDAR satellites in general(not restricted to the MDS-LIDAR)

2)Adopt MPE(Maximum Permissible Exposure) as the Laser safety criterion

How dose the ocular injury occur by LIDAR laser beam is shown in Fig. 1. At first, we must estimate the maximum safe diameter of telescope based on MPE (Maximum Permissible Exposure, which equivalent to ANSI standard). Then we proceed to estimation of how many persons will have ocular hazard in the LIDAR mission by probability analysis. The detailed procedure is shown in Fig.2. The maximum diameter of telescope is estimated from the safety coefficient for the LIDAR mission and the mean value of human pupil diameter. The safety coefficient is determined by the MPE standard. This is shown in Fig.3. For the estimation of how many person will have ocular hazard, it is necessary to know the number of persons enter into footprint. This is shown in Fig.4. For the estimation of the probability, we must know the data on telescope: the number of telescope and observation frequency distribution. In Fig.5 as an example of observation angle distribution, the data of KISO professional observatory is shown , and the distribution of telescope in the world from ILOC data base is shown in Fig.6. We can do the quantitative estimation of the probability based on these data and the mathematical model for the various LIDAR mission and for the various parameter values.

Actual probability of injury by laser beams

The following factors must be taken into consideration for calculation of probability.

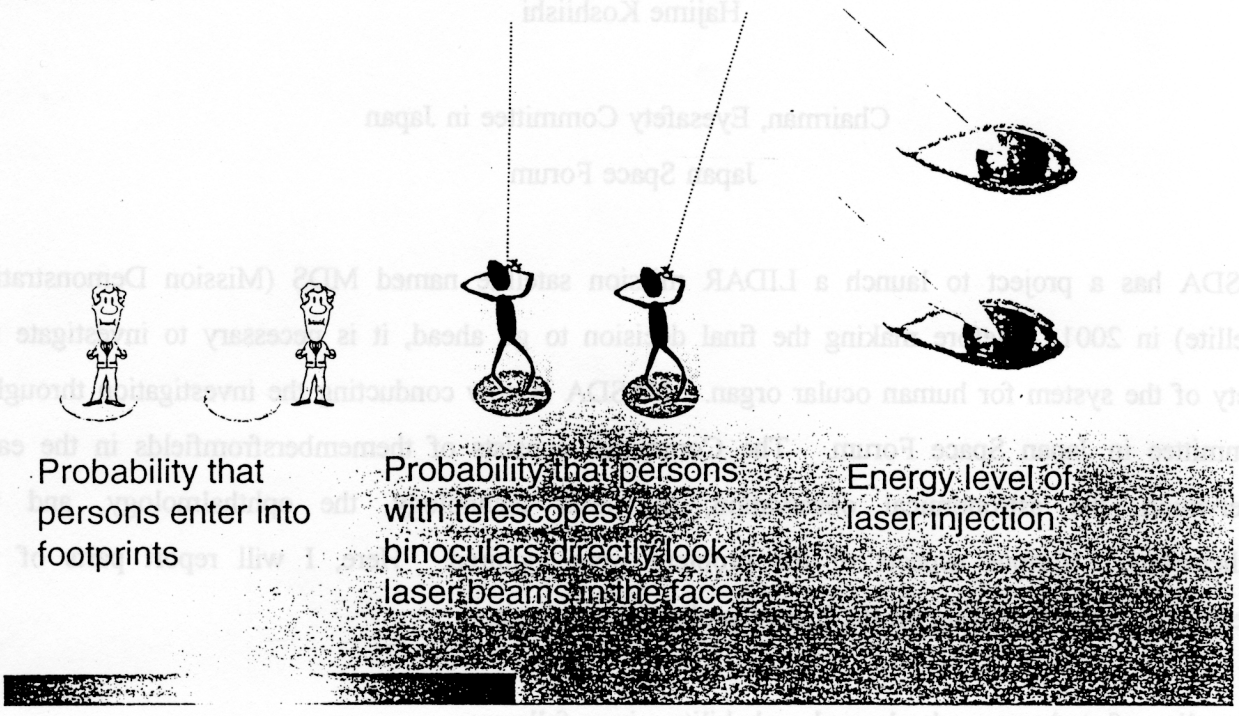

Fig.1 Occurence of actual injury by laser beams

Procedure of Hazard Probability study

1. **Estimate the safe maximum diameter of telescope**
2. **Estimate number of persons (N_0) enter into footprints**
3. **Estimate probability (P_C) that the person with telescope looks laser beam in the face directly**
4. **Estimate number of persons receive ocular hazard in the mission time**

$$\Sigma N_0 \times P_C$$

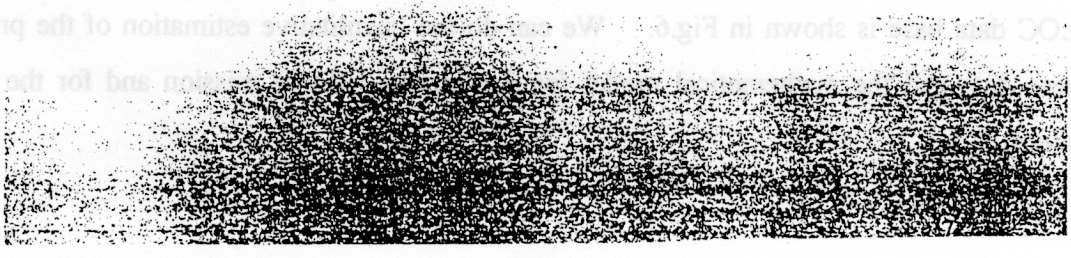

Fig.2 Procedure of hazard probability study

Estimation of safe maximum diameter of telescope

Safety coefficient =

maximum permissible exposure (J/m²) /

energy density on the ground (J/m²)

maximum diameter

= 7 (mm) × $\sqrt{\text{safety coefficient}}$

7 mm: diameter of pupil

Fig.3 Estimation of maximum safe diameter of telescope

Number of Persons Enter into Footprint: N_0

$$N_0 = N_{total} \times p_0 \times \frac{1}{\pi}\left\{\sin^{-1}\left(\frac{\sin\phi_1}{\sin\theta}\right) - \sin^{-1}\left(\frac{\sin\phi_2}{\sin\theta}\right)\right\} \times \frac{S_f}{S_e}$$

Where:

$N_{total} \times p_0$: Total number of telescope located in $\phi_1 < \phi < \phi_2$

$\frac{1}{\pi}\left\{\sin^{-1}\left(\frac{\sin\phi_1}{\sin\theta}\right) - \sin^{-1}\left(\frac{\sin\phi_2}{\sin\theta}\right)\right\} \times \frac{S_f}{S_e}$: Fractional rate of total footprints area in $\phi_1 < \phi < \phi_2$ to the Earth surface area

N_{total} : Total number of telescope in the world

p_0 : Fractional rate of telescope number in $\phi_1 < \phi < \phi_2$ to N_{total}

ϕ_1, ϕ_2 : Lower and upper latitude of considered part of orbit

θ : Inclination angle of satellite orbit

S_f : Total footprint area in the mission time

S_e : The Earth surface area

Fig.4 Estimation of number of persons enter into laser beam footprints

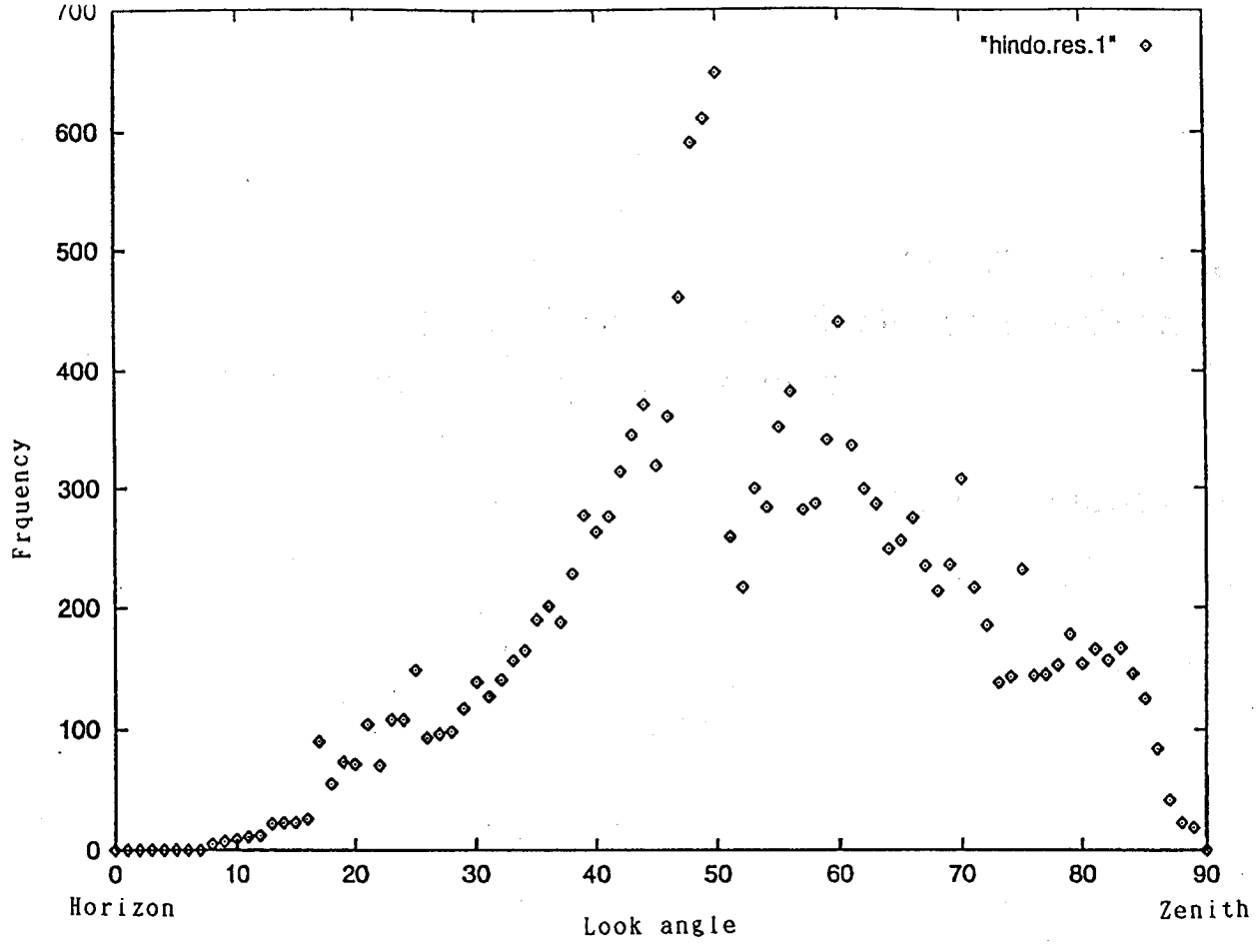

Fig.5 Example of observation frequency distribution on KISO observatory

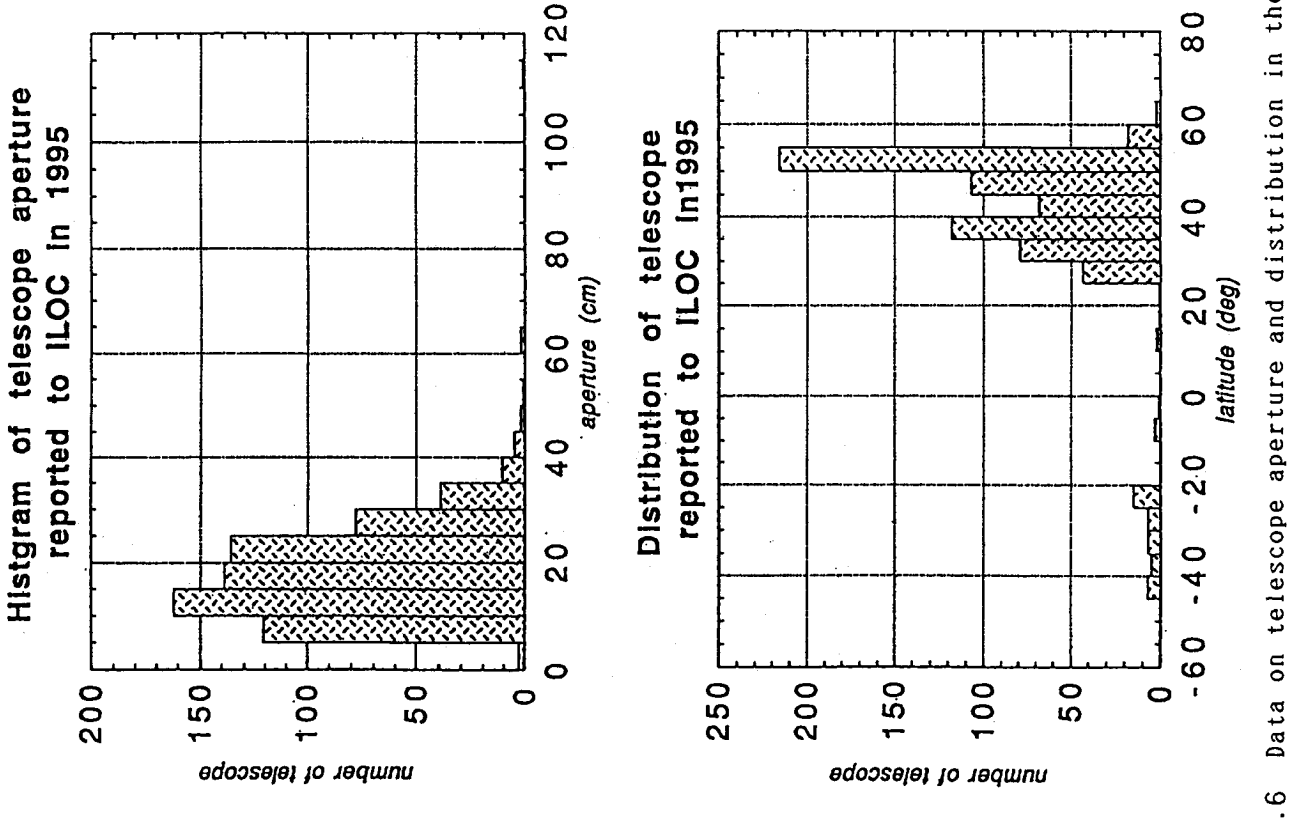

Fig.6 Data on telescope aperture and distribution in the world