DEVELOPMENT OF SURVEYING ROBOT

Masayuki Takasu, Tsutomu Sato, Shigeyuki Kojima, and Kazuhiro Hamada
Mechatronics Research Department, Institute of Technology,
Tokyu Construction Co., Ltd.

3062-1, Sonesita, Tana, Sagamihara-City,
Kanagawa, 229, Japan

ABSTRACT

The purpose of surveying robot is to streamline a series of work at sites, such as transportation and setting of surveying equipment, surveying, the recording of coordinates data, to achieve labor-saving and high efficiencies in surveying work.

Characteristics of surveying robots are shown below.

1) A precise survey can be made by a worker.
2) They can move across an up-and-down site with all equipment necessary for surveying including a total station, a precise instrument, loaded on them.
3) Errors caused by man in reading and writing coordinates data are eliminated, and coordinates data can be prepared efficiently at the site office.

This paper describes the purpose of the development of surveying robot, details of the robot, results of function-confirmatory experiments made at actual sites upon completion of the manufacture, and so on.

1. INTRODUCTION

Surveying work carried out for construction work of land development, expressways, or the like is very hard to improve its efficiency because of very wide working area, a lot of stations, site conditions that may vary significantly in a short period of time, and other reasons.

Work, such as installing surveying instruments and reading/recording coordinates data, which are still being made manually, is likely to cause errors by man including generation of installation errors and erroneous data entry. These have been major issues on surveying work for construction work.

Then, aiming at labor-saving and improving efficiency in surveying work, we have developed surveying robot that carries out at sites transportation and installation of surveying instruments, surveying, recording coordinates data, treating and managing coordinates data at the site office.

2. BACKGROUND OF DEVELOPMENT

2.1 Investigation by Hearing

Investigation by hearing was carried out on actual surveying work made in land development work to establish the goal of the development of surveying robots, and the objective work of surveying robot were made clear.

The investigation by hearing revealed the follow-up matters.

1) At a site just after the commencement of construction work, there are many slopes that refuse access by vehicles. Therefore, all work must be carried out manually, and the number of stations per day is very few.

2) Setting work of stations for building construction work, including laying pipes underground, stone masonry work, and side-gutter work, requires high accuracy, and yet stations are many.

3) Almost all survey work is carried out by plural workers, and labor-saving is hard.

4) Transportation and installation work of surveying equipment takes time, and a reduction in number of workers and working hours is difficult. Then, setting work of stations for building construction that requires many man-hours and high accuracy was decided to be the object of surveying robots, and automation of transportation and setting work of surveying equipment and surveying work to be basic policies.

2.2 Setting Goal of Development

Based on the basic policies, the goal of the development was decided to be the following matters.

a) The robot can move to the surveying positions with all equipment's mounted on it, and saves time required for installation of surveying instruments.

b) The robot can reduce labor to carry equipment.

c) One worker can set a station.

d) An accuracy similar to that of conventional surveying can be secured.

e) Connected to a CAD system or the like, surveying data can be written and read.

3. COMPOSITION OF SURVEYING ROBOT

3.1 Composition of Surveying Robot

The composition, specifications, and operational principle are stated below.

The surveying robot consists mainly of an automatic follow-up type total station, mobile truck, and leveling stand. The outward appearance of the surveying robot is shown in Photo 1, and the construction plan and the specification table are shown in Fig. 1. and Table 1 respectively.

1) Automatic follow-up total station

One worker can carry out all surveying work with this automatic follow-up type total station that is provided with an automatic search and follow-up mechanisms of the reflecting prism.

A CCD camera mounted on the top of the telescope catches the image around a collimation point, and the image is projected on the liquid crystal display on the operation panel. Watching this image, collimation work of the reflecting prism can be made quickly.

In addition to the display that projects the image of the CCD camera, switches for easy operation of the total station are arranged on the operation panel.

Distance and angle data measured by the automatic follow-up type total station are sent to the distant data recorder, where three-dimensional coordinates values of the reflecting prism are displayed. For setting work, therefore, no worker is required who collimates the reflecting prism, records the distance and angle data, and send signals to the surveying positions, which makes rationalization of the work and labor-saving possible.

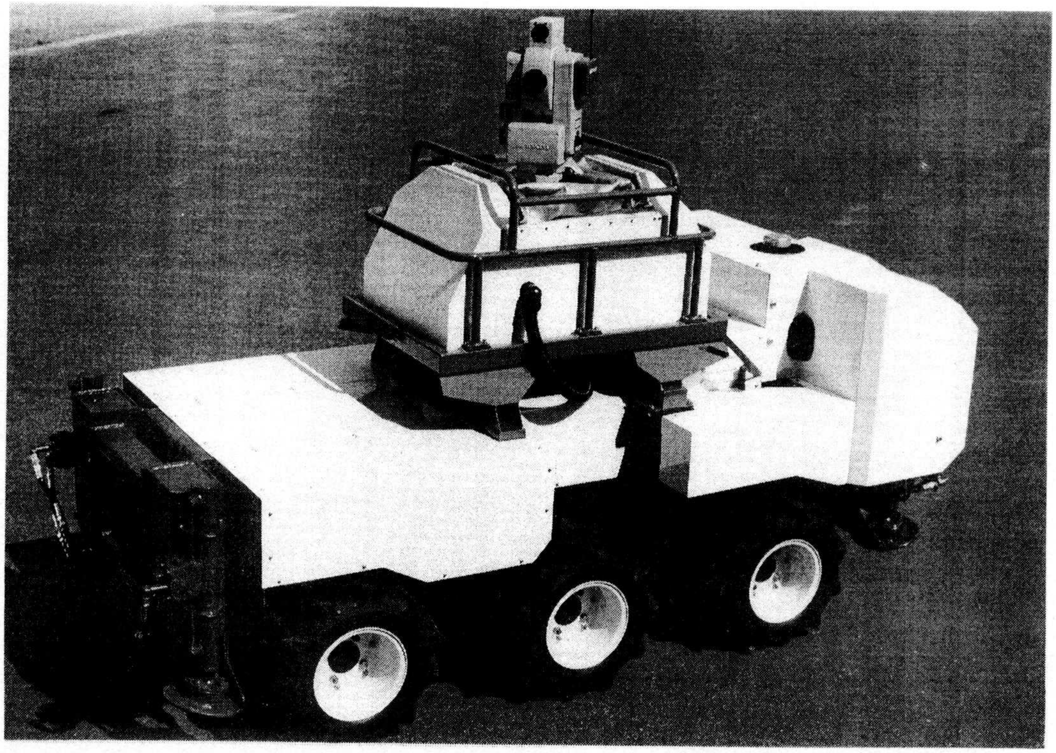

Photo 1 Surveying Robot

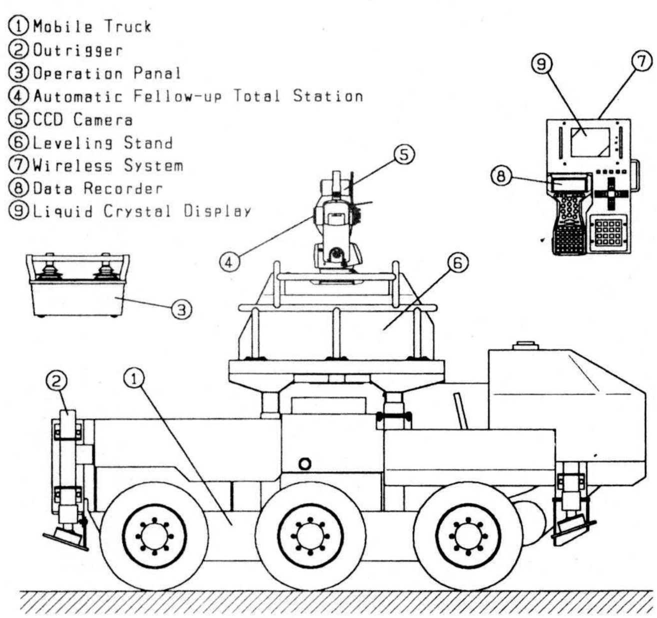

Fig. 1 Construction of Surveying Robot

Table 1 Table of Specification of Surveying Robot

●Total Station	
·Mesurable range	·Small size prism: 4～400m ·Normal size prism: 7～700m
·Mesurement accuracy	±(3.0+2ppm×D)mm
·Follow-up speed	10° /sec
●CCD Camera	
·Lens	Zoom Lens (×8)
●Leveling Stand	
·Correctable angle	±30°
●Mobile Truck	
·Gradability	30°
·Running speed	0～7.5km/h
●Miscellaneous	
·Weight	11.5kg
·Size	2.270×1.000×1.620mm

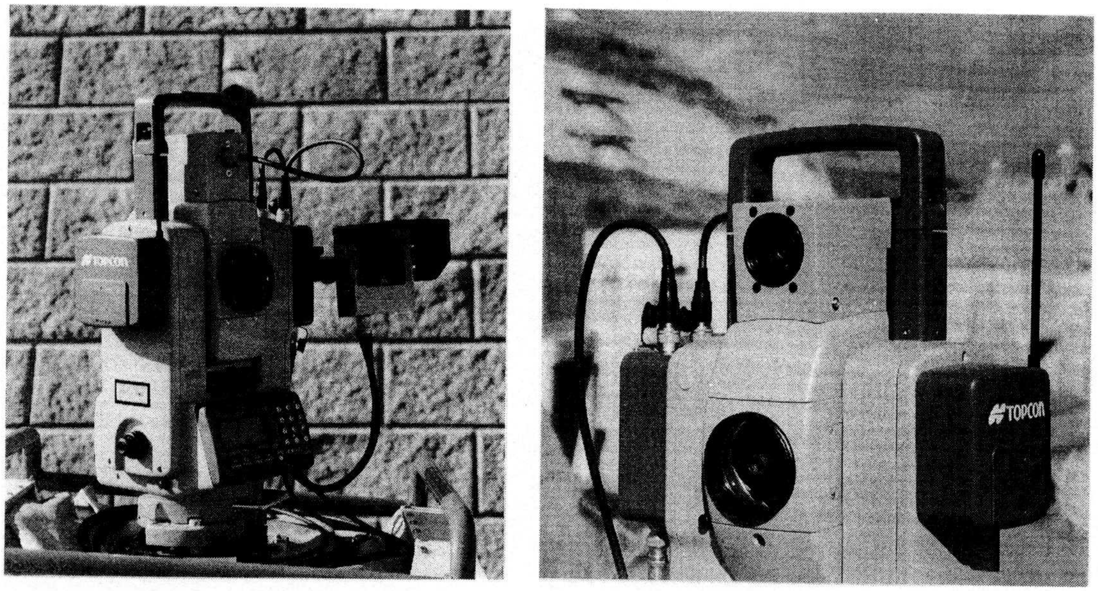

Photo 2 Automatic Follow-up Total Station

2) Mobile truck

An engine-driven six-wheel type mobile truck for running on uneven ground was employed. Free running in sites of public work requires high gradability. This wheels type mobile truck can move on slopes with inclinations up to 30 degrees, and it generates few vibration in running, which causes little affection to the total station loaded on the truck.

It is fully maneuvered wirelessly and can be controlled from a distant location. A wireless system was selected that was operatable safely and not affected by noises and the like.

Outriggers were provided around the mobile truck to prevent shakes and vibration generated in surveying work. So that four outriggers may be evenly loaded, the cylinder of each outrigger is provided with a pressure sensor which controls the force applied to each cylinder.

3) Leveling stand

The leveling stand is a stand for the total station that has two functions, that is, automatic inclination correction and vibration absorption.

The former maintains the automatic follow-up total station horizontal when the mobile truck is on a slope. The stand to which the total station is fixed is provided with an inclinometer, and the total station is kept horizontal based on the output of the inclinometer. Since the level correcting range is ±30 degrees, the location of robot installation is not limited.

The latter is a suspension mechanism that does not transmit shocks generated while the truck is running on uneven ground nor vibration of the truck to the total station. Applying shocks or vibration to the total station, a precise instrument, for a long period of time may cause troubles or a reduction in accuracy. The vibration absorbing function makes it possible
to run on uneven ground with the automatic follow-up type total station loaded on the truck.

3.2 Composition of Surveying System

The composition of the surveying system including the surveying robot is shown in Fig. 2.

Since the surveying robot reduces man-hours for surveying work at sites, and it is connected with the CAD system and survey-supporting systems, coordinates control work at the site office can be carried out efficiently.

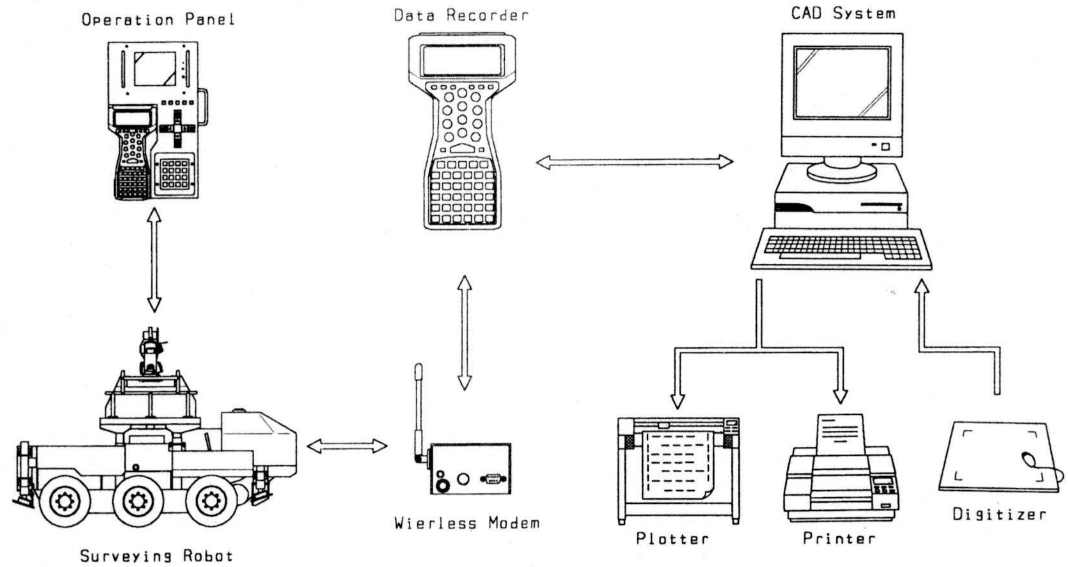

Fig. 2 Construction of Surveying System

4. WORK PROCEDURE

Work procedures of the surveying robots is shown with an example of setting work of a station for a structure. (Refer to Fig. 3.)

1) Preparatory work for surveying

Coordinates data of the setting point and those of the traverse point that is to be the station for working out station points are stored in the data recorder. Then, it is possible to connect with the CAD system to write coordinates data directly.

Equipment required for surveying (reflecting prisms for the station, surveying stakes, tripods, and so on) are loaded on the surveying robot.

2) Move to surveying point

The robot is operated and moved to the surveying point. While traveling, vibration absorbing function of the leveling stand is used not to transmit vibration nor shocks to the total station.

3) Setting surveying robot

Upon arrival at the surveying point, outriggers of the traveling truck are stretched to fix the body. Next, the vibration absorbing unit is fixed to restrain the move of the total station. At the same time, the inclination correcting function of the leveling stand is used to maintain the total station horizontal.

As the station for calculating station points of the surveying robot, the reflecting prism is mounted right above the traverse point.

4) Working out stations

Watching the collimation point of the total station projected on the monitor of the operation panel, reflecting prisms set on traverse points are collimated one after one, and angles and distances are measured.

Based on information on measured angles and distances to reflecting prisms, calculation of stations are carried out by resection.

5) Setting work

The data recorder is disconnected from the surveying robot, and moved to the vicinity of the setting point. The automatic follow-up station follows automatically the reflecting prism that a worker carries, and sends its three-dimensional coordinates values to the data recorder. Watching the display of the data recorder, the worker locates the point where setting is to be made. He piles a surveying stake, and moves to the next setting points.

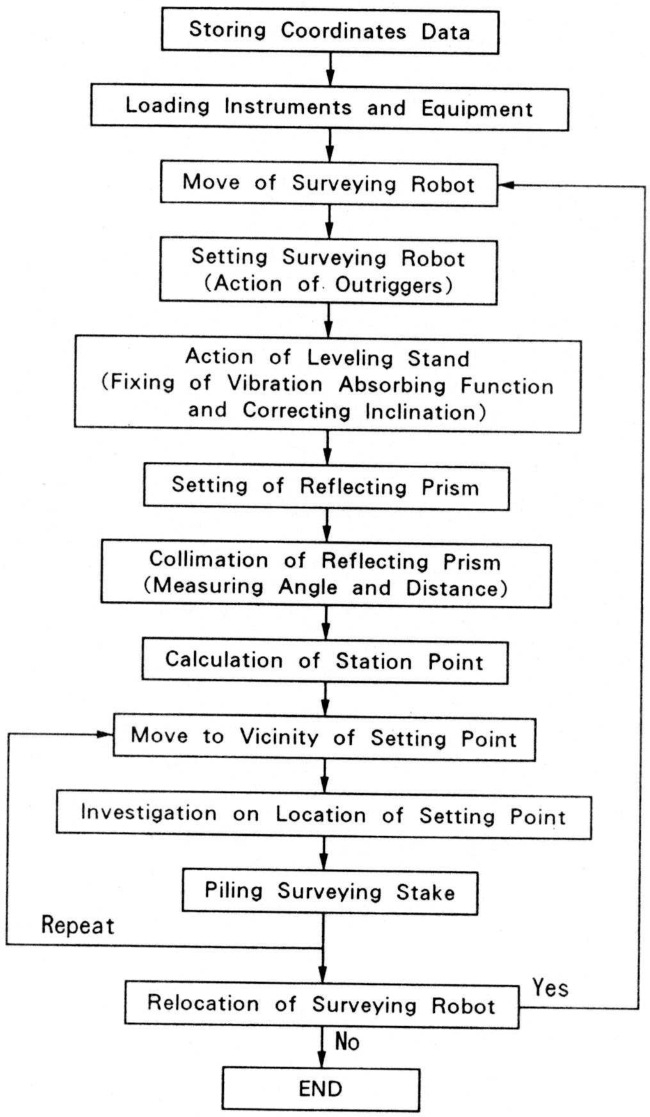

Fig. 3 Flow of Work Procedure

5. RESULTS OF EXPERIMENT AT SITE

Upon completion of the manufacture of the surveying robot, the robot was introduced to land development sites to carry out a functional confirmatory experiment and accuracy confirmatory experiment.

As the results of experiments, the following effects were confirmed.

1) Labor-saving was realized because only one worker could carry out the work. Work efficiency was improved and the number of points that one worker can set in a day.

2) Time and work for transportation were reduced because all the equipment necessary for surveying were loaded and moved on the truck.

3) Since coordinates data could be written into the surveying robot directly from the CAD system, errors caused by man was eliminated, and time required for coordinates data entry was much reduced.

4) The accuracy was the same as that by conventional surveying methods.

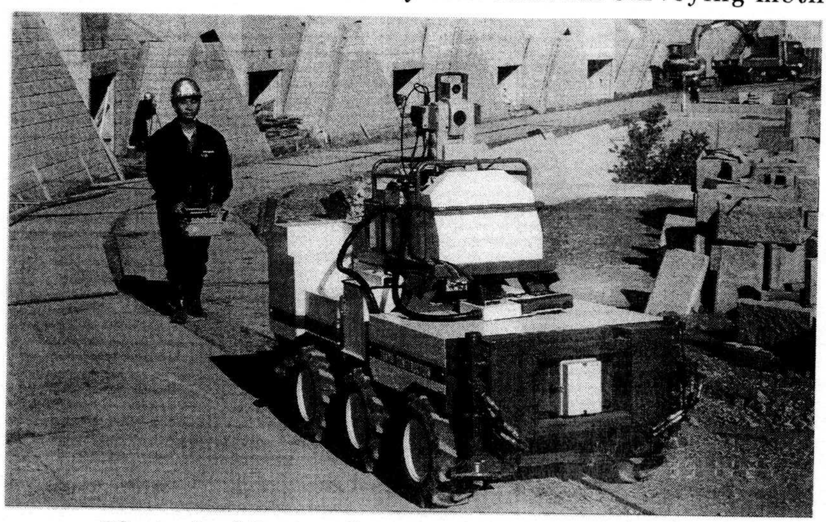

Photo 3 Moving Status of Surveying Robot

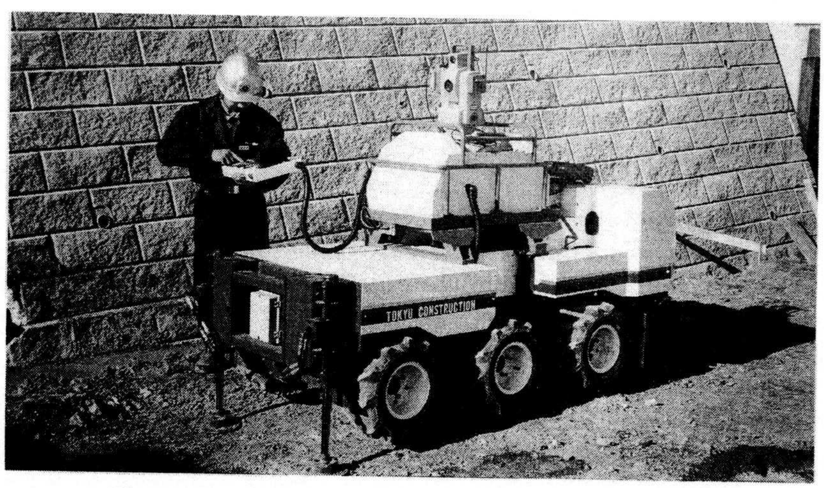

Photo 4 Setting Status of Surveying Robot

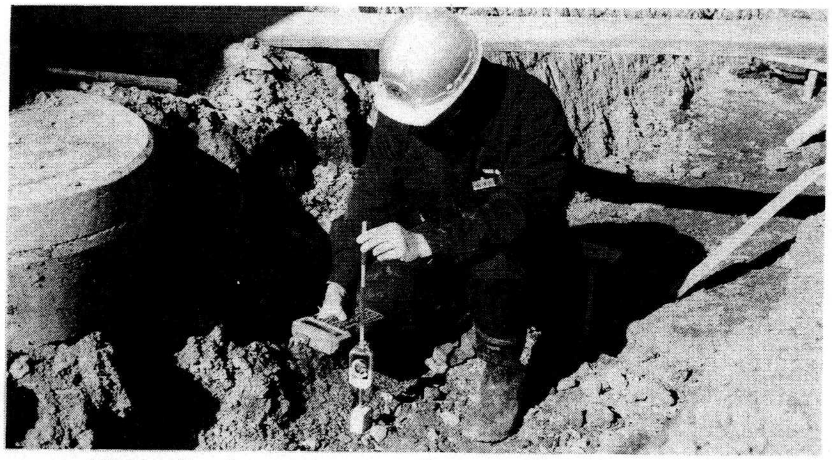

Photo 5 Investigation Status of Setting Point

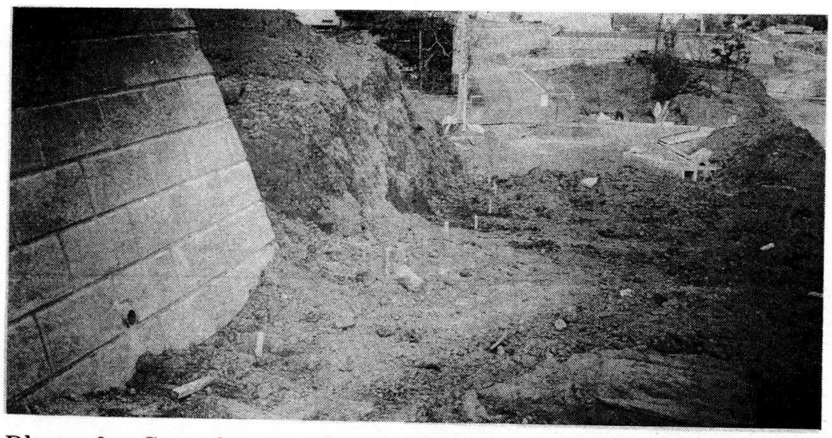

Photo 6 Completion of Leveling of Station for Side-Ditch

6. CONCLUSION

Placing great importance on the following matters, the surveying robot was developed.

1) Development of the mobile truck and the leveling stand that can move on uneven ground with the automatic follow-up type total station loaded on the truck, and by which a survey can be made even on a slope.

2) Development of a control unit, software, and accessory devices that enhance workability of the automatic follow-up type total station.

It was confirmed by experiments made by introducing the robot into actual sites that the surveying robot could achieve objectives that had been set at the early stage of the development.

We are, however, going to improve software and accessory devices to enhance further the workability of the surveying robot. We are going to apply this technology not only to surveying work at land development sites but also to surveying and measuring work for tunneling work, expressway construction work. and the like.

Finally, we are very grateful to collaborators and supporters on the development of this