The PhotonStar Project

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ABSTRACT

The PhotonStar SETI project is an enterprise to detect extraterrestrial laser signals that involves many individual small telescopes acting together as a geographically diverse large array which together comprise a large collection area, thereby, offering a better chance of detection if signals exist. Widely separated small telescopes, each with a sensitive photon detection capability, can be aimed simultaneously at the same star system with precise timing that enables looking at the same time for short pulse detection. Each individual telescope can be located via GPS so that the differential distance from the star compared to every other telescope can be determined beforehand. Coordination via the Internet would enable each telescope to operate as one element of the array. This project allows direct public participation by amateur astronomers into the search for extraterrestrial intelligence as there are thousands of telescopes of eight inches or greater in use, so that the total collection area can be very substantial with public participation. In this way, each telescope is part of a larger array with data being sent via the Internet to a central station. This approach is only feasible now with the advent of GPS, the Internet, and relatively low-cost single photon detector technology.

Keywords: Laser, Signals, SETI, Optical, Single, Photon, Detection, Collectors, Pulses, Internet.

1. INTRODUCTION

The PhotonStar SETI project is an enterprise to detect extraterrestrial laser signals that involves many individual small telescopes acting together as a geographically diverse large array which together comprise a large collection area, thereby, offering a better chance of detection if signals exist.

Widely separated small telescopes, each with a single photon detection capability, can be aimed simultaneously at the same star system with precise timing that enables looking at the same time for short pulse detection (within 10 nanoseconds or less). Each individual telescope can be located via GPS so that the differential distance from the star compared to every other telescope can be determined. Coordination via the Internet would enable each telescope to operate as one element of the array.

The power of using an array of individual telescopes is that there are thousands of telescopes of eight inches or greater in use so that the total collection area can be very substantial. The signal photon flux from the star system is obviously the same whether there is one 10,000 sq. ft. collector or 10,000 one sq. ft. collectors. Therefore, if there are signal photons that the 10,000 sq. ft. collector would have detected, that same number would be detected in total by the 10,000 small collectors of 1 sq.ft. each. If the flux is low, a few detectors of the 10,000 will still receive photons even if the majority detects nothing. Poisson statistics will apply and some detectors must receive a photon such that the average number of photons being detected is the same whether we use one 10,000 sq ft. detector or 10,000 one sq. ft. detectors.

In this way, a truly interactive system, whereby each telescope is part of a larger array results with data being sent in real time via the Internet to a central station to analyze the complete data from all participating telescopes. Specific directions prior to the measurements will enable each telescope to aim at the proper star and look at the correct time with the laser detector.

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Each receiver has its own set of coincidence detectors to remove internal noise results. Direct comparison of results, when the array is pointed at other less likely star systems can be made to insure a reference point. Although it is unlikely that a pulse is being detected at the same time by widely separated receivers if it is not from an intelligent source, there is some low probability any such event would occur. If so, any such event would be more thoroughly examined to replicate the results.

This system enables the participation of both amateurs and professional astronomers for the cost of a laser receiver at each site. This is estimated, if built in significant quantities, at around $5,000 each. In large quantities, this cost may be reduced to $2,500 each. There is necessity for appropriate software for the system to be furnished to each participant, and the output has to be processed in the computer for forwarding to the Internet.

The key, however, that makes this system attractive, is that (1) it avoids the necessity of building a large optics multi-million dollar system to detect pulse laser extraterrestrial signals, (2) it enlists anyone who wants to into becoming a real partner in search of Optical SETI (3) it is less weather dependent because of the wide geographical diversity, (4) it is only feasible now with the advent of GPS, the Internet and relatively low-cost single photon detector technology and (5) the system can continue to grow as more receiver stations are added.

The laser receivers are designed such that they are readily installed on existing computerized telescopes such as those manufactured by Meade and Celestron and together with the software, offer a turnkey approach. No special knowledge is required to become a participant.

It is not too presumptive to believe that in a few years, thousands of these individual telescopes/laser receiver systems can exist and be coordinated into a massive, continuing search for optical extraterrestrial signal pulses and have much greater likelihood of signal detection than any near-term optical approach. One or two star systems may be examined each week, continent by continent, requiring only an hour or two a week per participant. The 100 most likely star systems can be examined in a year's time.

2. SYSTEM DETAILS

It has been proven [1-7] that short pulses in the optical regime offer especially, at low duty cycles, a high number of bits per photon and is a very efficient information transfer waveform. In these systems no knowledge of the exact wavelength is needed which greatly simplifies the search [8-12].

Normally, if one attempted to detect short laser pulses (~2 nanoseconds or less) one would use one telescope and photon receiver. However, if the signal is expected to be very weak, a large photon collection area would be needed. The cost of large telescopes is significant and performance is dependent on weather and geography issues. However, attempting to use more than one telescope immediately gets into timing issues as each telescope may be located a significant distance away from each other and therefore, the time at which a short pulse reaches each telescope is quite different and the difference is also changing with each pulse as the source is also changing in relative angles to the different telescopes. See Figure 1 (a) and (b). One nanosecond is one foot in line of sight distance.

By knowing each small telescope's location precisely in lat, long and altitude and through coordination through the Internet, each telescope can be aimed at the same small sky segment. Each telescope has a sensitive short pulse laser receiver. Thousands of small telescopes can be coordinated in this fashion using the Internet and GPS. It becomes possible to use the many existing thousands of small telescopes by adding a short pulse laser receiver and integrating it with the telescope. Through the Internet or through other means (RF, etc.) the key information on pulse detection and time of detection can be sent for the analysis can be done on the number of receivers recording detection and the time of detection. The basis for this system working is that the photon flux from the laser source is the same whether one uses a 10-meter diameter optical telescope or thousands of small telescopes that add up to the same collection area. If the large telescope detected 10 photons (on the average) in a single nanosecond, then 10 photons (on the average) should have been detected by the thousands of small telescopes. Due to the photon statistics, variation from the average will take place during a particular measurement

Although most of the telescopes may record no signal, taken together, some of the telescopes will have detected a signal pulse and sent their detection information to the central processing station. Each time a weak pulse is detected, a different set of the small telescope family of receivers will detect the pulse while most will not. But some will have to if the same collection area as the one large telescope is used and it would have detected the signal. Since location can be specified with GPS to a few centimeters, and the delta distance for each telescope to a location in deep space can be calculated as a changing number with angle changes as the earth rotates, accuracies are sufficient to detect ultra-short laser pulses; one nanosecond represents one foot of distance that light travels. It is assumed the detectors employed are fast enough to distinguish one-nanosecond pulses. See Figure 2 for the system block diagram.

In this way, by using a diverse geographical array of small telescopes, the equivalent performance of a very large telescope can be attained—in fact, in principle a greater collection area can be achieved than can practically be built with one large telescope on Earth.

In Figure 3, the receiver hardware configuration is shown. The existing telescope and PC's can be integrated together with the new equipment—the single photon module to enable each receiver to detect short pulses. Unique software will be provided as well to enable the necessary interfaces such as control of the telescope control on where and when to look at a particular star system and to record signal outputs and to transmit that data with the time of detection to the website. Each receiver has its own ID number which tells the central processor at the website which telescope has detected a signal. It knows through prior GPS measurements exactly where that receiver station is located, which is necessary in order to establish detection of the signal in that detection by a number of receivers will take place 'simultaneously'. 'Simultaneously', we mean it takes into account the difference in distance each receiver is from the source at which it is pointing. If one receiver is 5,000 feet further away, it should detect the same pulse 5,000 nanoseconds later.

3. COMPARISONS WITH LARGE TELESCOPES

Figure 4(a) shows the collection area of large diameter telescopes. Figure –(b) shows the number of smaller telescopes such as a 12-inch telescope required to equal the collection area. Equivalent area can be achieved with a number of advantages over one large telescope. The difficulty in even procuring the use of a medium size telescope, let alone the few large ones, is high due to the fact it would have to be dedicated to be of real value for a serious search. Even getting a small amount of time on a large telescope is difficult. Although one can build a dedicated photon collector system, it remains expensive and a significant initial cost. The diverse array of smaller telescopes offer, the advantages of being less weather dependent, makes use of an existing infrastructure of telescopes and PC's and can grow steadily as stations can be added without affecting the system.

The ability to detect weak signals increases with collection areas. In a single large collection area receiver, more background photons will also reach the single detector at the focus of the system. With smaller collection areas, the background will be less of an issue (although obviously, for each detector, it will also collect less signal pulse photons). A wide-open spectral receiver (so no wavelength knowledge is assumed) becomes more feasible with a smaller collection area. False detections will occur on a number of small collection are receivers, but the central processor should be able to sort out false signals through time of detection.

4. RECEIVER CONSIDERATIONS

The photodetector package to go into the receiver needs to be chosen and optimized. The Single Photon Detectors made by Hamamatsu and Perkin-Elmer are two different candidates. The HPMT (hybrid photoelectron multiplier tube) and the solid state Hybrid-APD are candidate detectors. High-speed circuitry is required to properly process the pulse output so adequate determination of the time of detection can be made. If the pulse is broadened due to insufficient detector/electronics bandwidth, the accuracy of time of detection is affected. The likelihood of false detections increases as the pulse width broadens to 10 nanoseconds, such that it would be uncertain in which of the 5 nanoseconds or more, the pulse actually was detected. Any background photons that were in the five nanoseconds (in lieu of 1 nanosecond) may be considered 'simultaneous detection', when actually they are not.

Careful design that enables low-cost production is necessary, since the concept is to make the receiver affordable to amateur astronomers and astronomy clubs. Designs that may be suitable for one or two receivers may not fit the criteria to achieve a low-cost production unit. The future cost of the technology approach chosen is important as with one approach it may be feasible to cost far less in a few years, although today, it may be close in cost or even more than an alternate approach.

5. SEARCH CAPABILITIES

The use of a large collection area enables a relatively low energy per pulse laser be able to be detected from many light years away. An example is given in Figure 5, which shows laser energy of as small as 100 joules per pulse can be detected here on

Earth 200 light years away from its source. It is feasible to search two nights in a row at each of the 300 most likely stars in a year's time, although perhaps that would require more effort than expected from an amateur astronomer and volunteers. However, if two nights a week for a couple of hours per night each system can be operating, the 100 most likely candidates can be examined in a year's time. As one can make the system more automatic, very little of an individual's time could be required. The receiving system can run automatically, alerting the central station when a "real signal" seems to have been detected—then re-examination can take place.

6. CALL TO ACTION

What would be more fitting to have the discovery of intelligent life beyond Earth detected by the action of a democratic citizenry. The PhotonStar project can enlist the astronomers and astronomy clubs of the world in a common endeavor in which each is a part of a distributed system.

It should be noted that this project is sponsored by Laser Space Signal Observatory, a non-profit organization, and is behind the specific development. It is feasible that the receivers' cost for each telescope may be tax deductible as its only use for each person is for the PhotonStar project, a non-profit enterprise.

The market for this special receiver if we can get the cost down could be 100,000 users or over $200 million dollars—so we invite help from the photodetector companies. Also, we ask the astronomy clubs who have interest to contact us. We intend to promote interest in this project and to issue newsletters to all interested parties notifying them of our progress. The timetable we're on is strictly dependent on funding and that we can drive the costs down for a sensitive, short pulse receiver. We plan to put together a few sites and tie them together for trying out the system software. In parallel, we can proceed with low-cost receiver development. Thus, in a few years after system test and check-out, we may be ready to expand to many thousands of sites very quickly.

This is a project whose time has come; the details of implementation remain, but it appears quite feasible and quite desirable.

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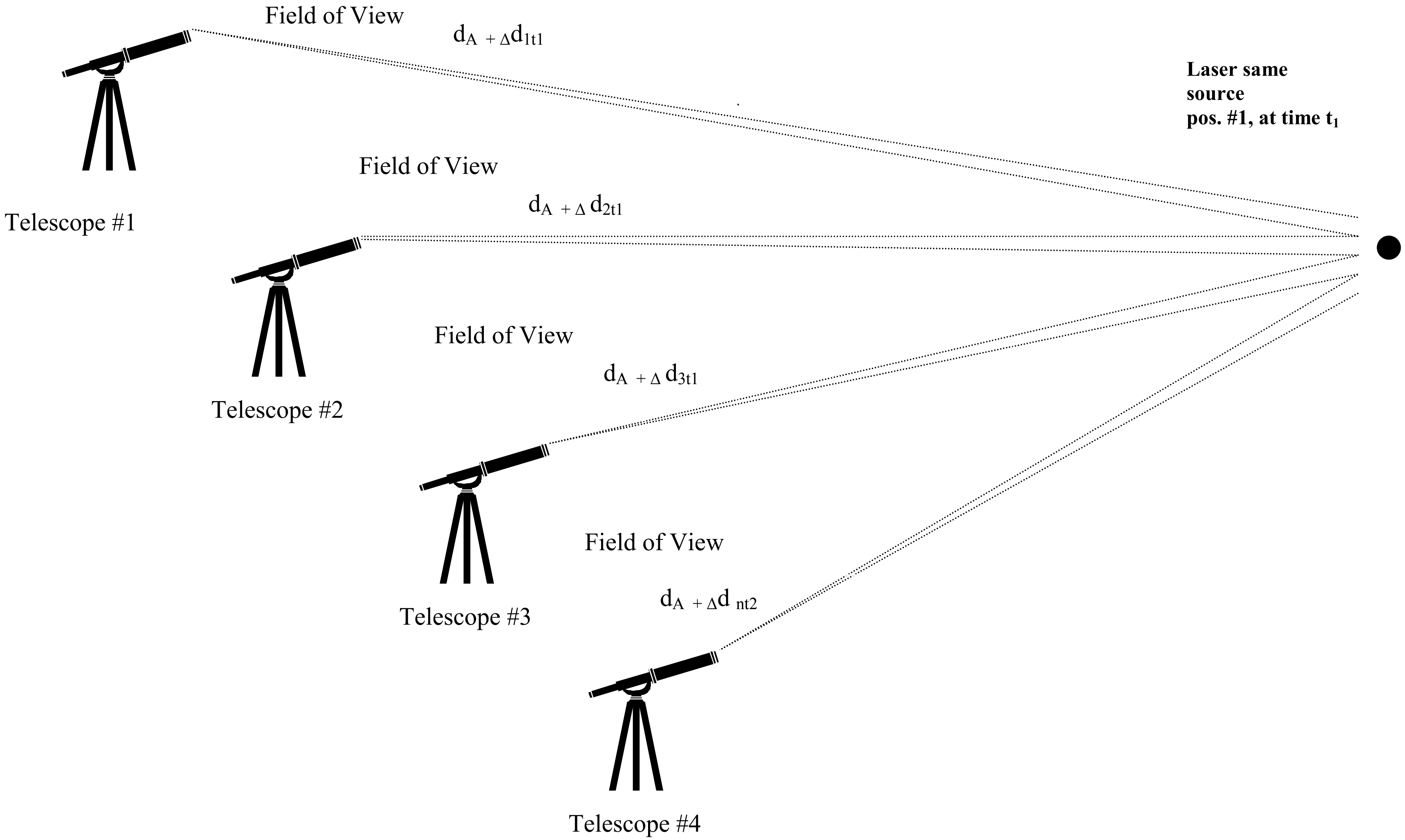

FIGURE 1A GEOGRAPHICALLY DIVERSE ARRAY OF SMALL TELESCOPES

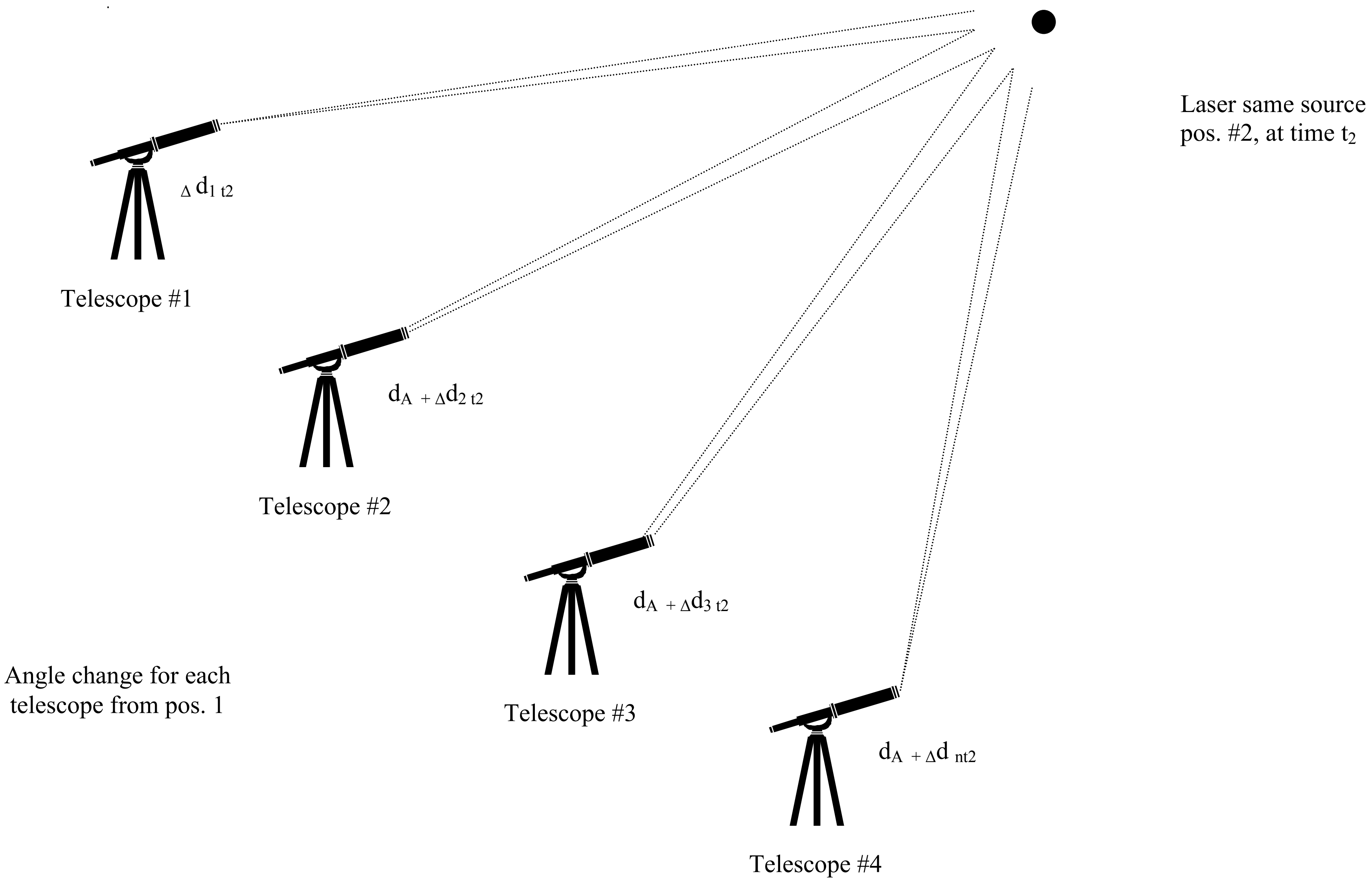

FIGURE 1B GEOGRAPHICALLY DIVERSE ARRAY OF SMALL TELESCOPES

FIGURE 2 SYSTEM BLOCK DIAGRAM
N TELESCOPES

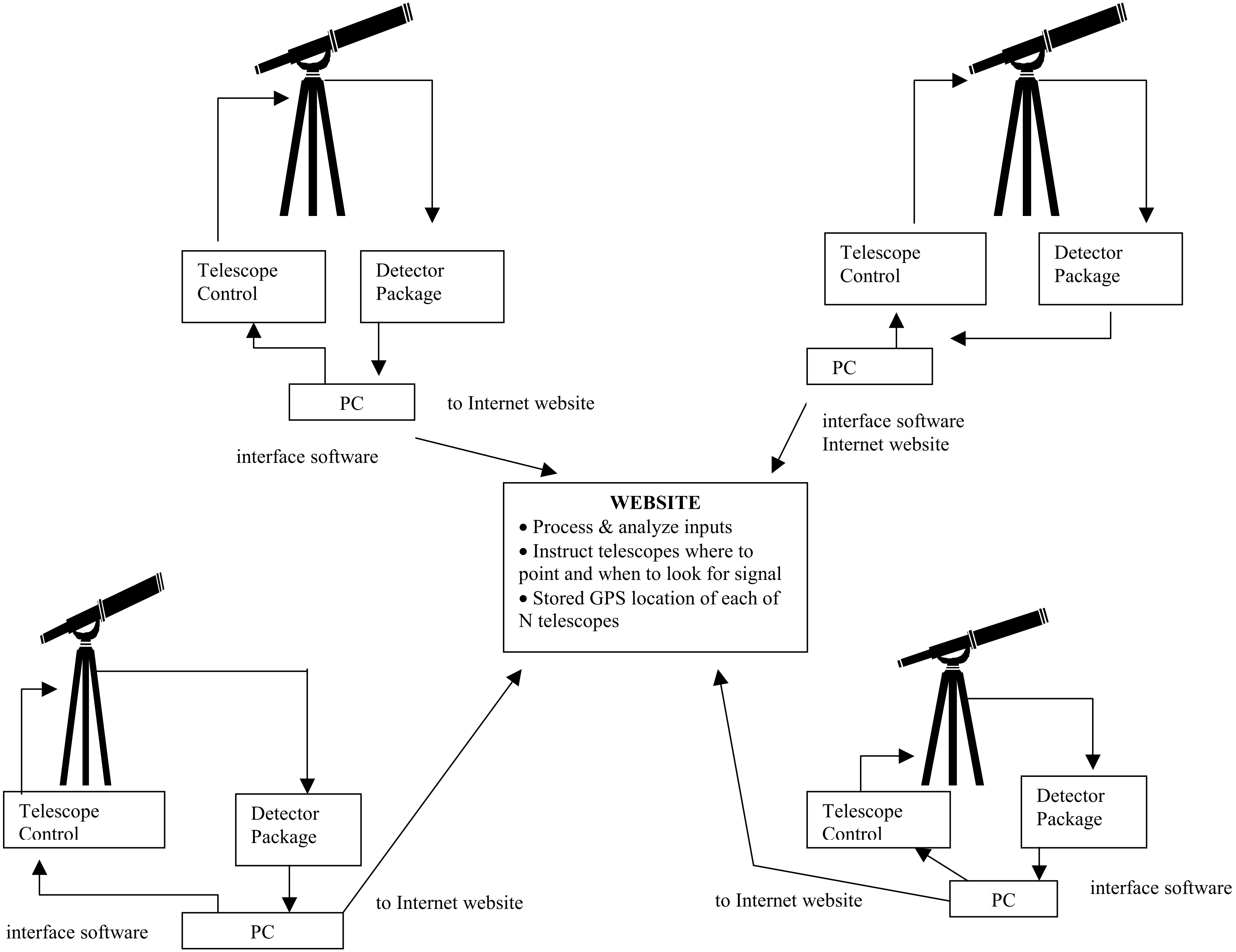

FIGURE 3   RECEIVER STATION HARDWARE CONFIGURATION

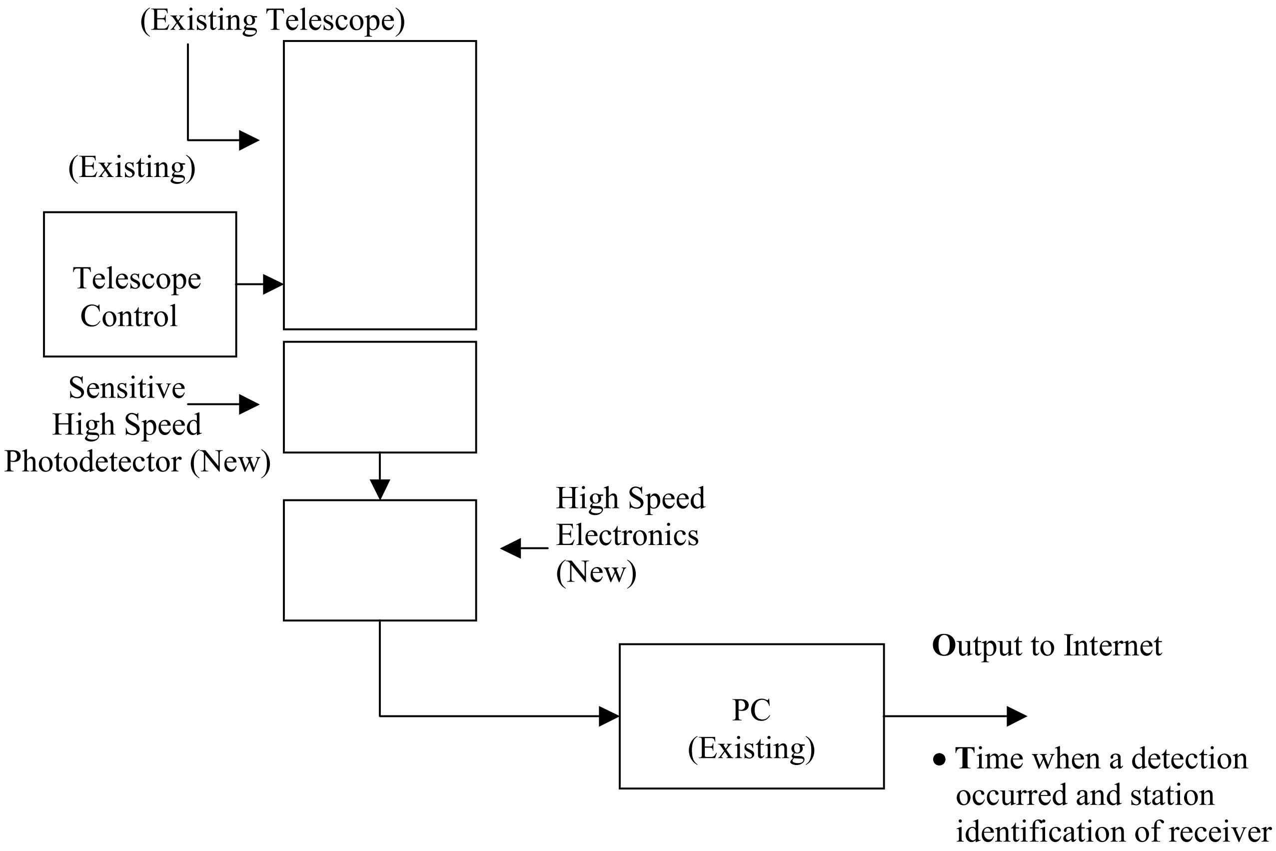

FIGURE 4(a) PHOTON COLLECTION AREA

Large Telescopes	Area (meters^2)
3 meter diameter	~7.0
10 meter diameter	~79
30 meter diameter	~707
Small Telescopes	
12 inch diameter	~0.073

FIGURE 4(b) COLLECTION AREA OF N SMALL TELESCOPES

N	Area (meters^2)
1,000	73
~9,700	707
~100,000	7300

FIGURE 5 DETECTABLE PHOTON FLUX

- Assume 10% detection efficiency
- Assume single photon detection
- Assume equivalent area of 30 meter diameter telescope (9,700 12-inch telescopes)

Photon flux is 10 pulse photons/707 m^2 or 1.4×10^{-2} photons/m^2

A laser 200 light years away with a 1 microradian beam would require a pulse output of approximately 100 joules to achieve this photon flux.