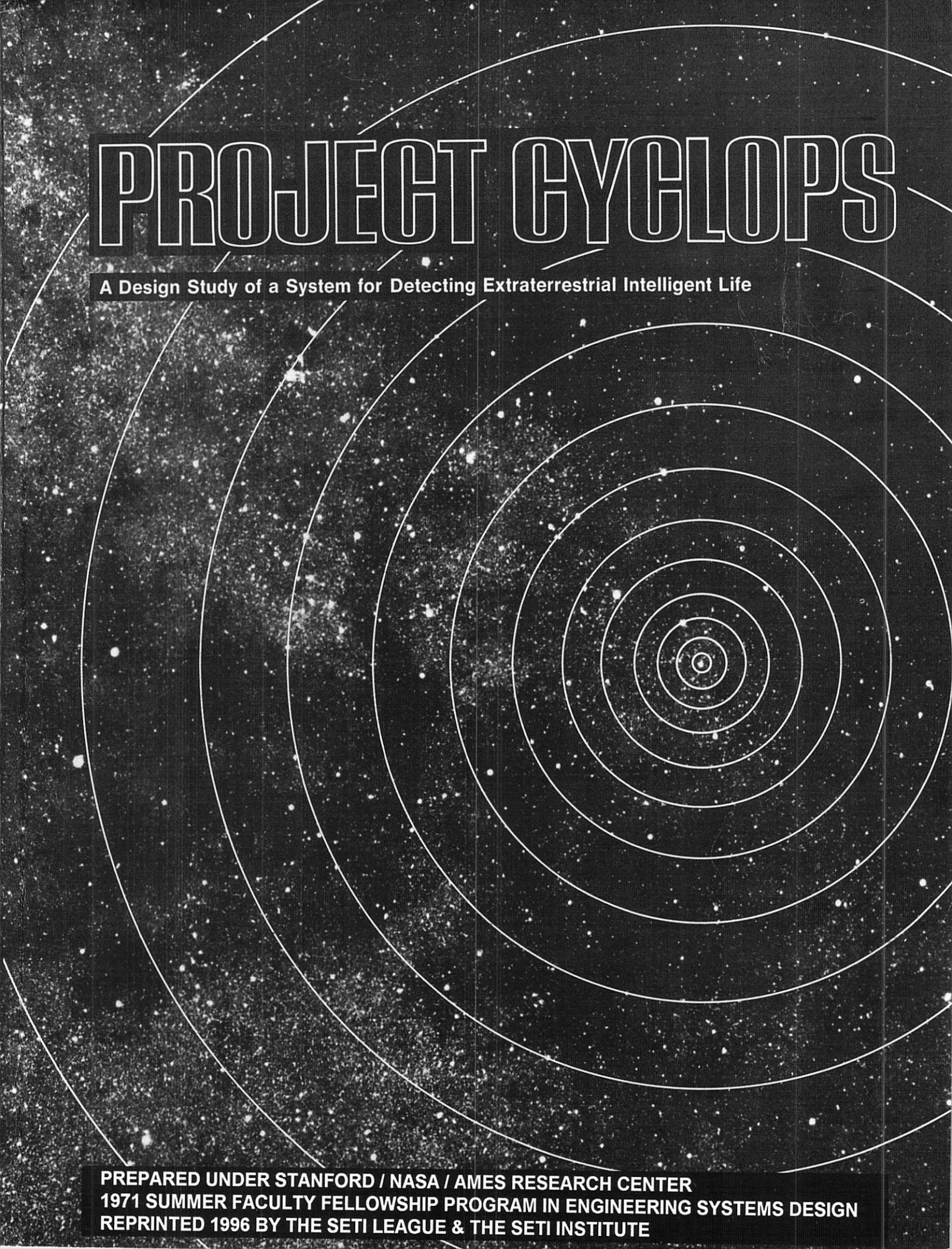

PROJECT CYCLOPS

A Design Study of a System for Detecting Extraterrestrial Intelligent Life

PREPARED UNDER STANFORD / NASA / AMES RESEARCH CENTER
1971 SUMMER FACULTY FELLOWSHIP PROGRAM IN ENGINEERING SYSTEMS DESIGN
REPRINTED 1996 BY THE SETI LEAGUE & THE SETI INSTITUTE

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PREFACE TO THE SECOND PRINTING OF PROJECT CYCLOPS

It is twenty-five years since the Cyclops Study. Although the available technology has changed enormously, the question of whether we are alone, or even near enough to other life to permit signal acquisition and subsequent communication, remains unanswered. The failure is essentially political. At its heyday under NASA auspices, the SETI budget was 1/10% of the total space budget. This in turn was less than 1% of the Federal budget. Even this small amount was too much for some Congressmen. If this is the maximum amount we can expect the political process to designate for the search, we will have to devote centuries to the task and may never succeed. Successful governmental support depends on a rational process and an educated electorate. Neither condition seems to be met at present.

The SETI system described in this report is, in a sense, a monument to obsolete analog technology. The digital revolution of the last two decades has made it possible to achieve better performance than the Cyclops optical data processing, for example, would allow. Instead of a mere 100,000 channels, the SETI Institute's Phoenix system resolves 20 MHz into the equivalent of 60 million channels in real time. Other SETI efforts, such as BETA and SERENDIP,* have comparable or even larger channel counts.

Low noise receivers have become cheaper. Optical fiber–a bright promise in 1972–would be the medium of choice today to tie together the elements of the Cyclops antenna array. Almost certainly the received signals would be digitized at the antenna elements and handled as digital data streams from then on.

We still do not have a cheap alternative to a phased array of large elements to provide collecting areas of square miles, expandable as the need for more sensitivity becomes clear. However, it is worth noting that if the radiated power of a SETI system in its transmit mode, and the collecting area in its receiving mode, are kept in balance as it is expanded, the range limit will be proportional to the investment. This means that the number of stars that can be tested increases as the cube of the investment. If present systems can reach out 100 light years and thereby interrogate 1,000 Sun-like stars, only a ten-fold increase would provide access to the million or so such stars within 1,000 light years. At this point, other problems would loom, problems such as the number of beams to be radiated and the time required to test a million stars, most of which are hundreds of light years away.

Although some of the arguments cited in the report for the prevalence of life have lost their impact, others have replaced them. We no longer trust the evidence for companions around Barnard's star, and others. But instead the years have revealed dust disks about young stars; disks out of which planets may have formed. Organic molecules have been discovered in space. Fossil evidence for life 3.8 billion years ago has been discovered; a mere blink of a cosmic eye after liquid water first covered the cooling surface of Earth. In all, the prospects for other intelligent life in the universe seem as bright as ever.

Earth-based interference has grown and is still growing. Systems involving simultaneous reception at two sites appear to be effective in testing the ETI or RFI nature of candidate signals, and thus help speed the observations. But even these systems can be overcome by too much RFI.

At this writing it appears important to establish SETI as an enduring effort. In this way it will be possible to spread the cost over decades, and to attract talent for equipment and strategy improvement as well as for observing staff. This is also the only way to extend the duration of our testing of stars to a significant fraction of cosmic time.

A sustained effort could become a widely recognized and unifying program that might prepare the people of Earth for the changed awareness that success in SETI would bring. To change humankind's attitude from xenophobia to xenophilia would be a most significant advance.

Bernard M. Oliver
SETI Institute

August 23, 1995

* Discussion of several other SETI efforts, including BETA and SERENDIP. can be found in the proceedings of the 1993 Bioastronomy Symposium in Santa Cruz, California, 16-20 August 1993 (see "Progress in the Search for Extraterrestrial Life," G. Seth Shostak, (ed.), Astronomical Society of the Pacific Conference Series, Vol. 74, 1995).

INTRODUCTION TO THE SECOND PRINTING OF PROJECT CYCLOPS

This book changed my life! When I first saw the Project Cyclops report, it was unheralded and buried in a heap of impenetrable and inconsequential government-published monographs with a sign saying "take me away." I was old enough at the time to have finally abandoned any science-fiction-based hope of a "hyperdrive" or other faster-than-light form of communication, and sadly, did not expect to find a replacement. I was young enough to still have the "spare time" to read Project Cyclops, and I did so – cover to cover. The report renewed my hope in the possibility of interstellar communication, and neither the uniformly negative result of SETI thus far nor our purblind elected officials have dissuaded me from that hope.

Project Cyclops was the original "blueprint" for a Search. I do not bemoan the economic difficulty of building the antenna system described in this blueprint. Rather, I am encouraged by the fact that advances in the art and science of computing and digital signal processing have brought many of the capabilities of Cyclops into the realm of the amateur experimenter. The mission of The SETI League is to encourage such experimentation. I can only hope that this reprint of Project Cyclops will change other lives by inspiring people to contribute in whatever way they can to the SETI effort. Perhaps one of its future readers will be the first to find the signal that will change *all* our lives.

Between the time this reprint was planned and its printing, Barney Oliver, the chief author of Project Cyclops, died. Apart from his work directly on SETI, his work at Hewlett-Packard was also a major influence in enabling the technology that allows SETI to multiply in effectiveness year after year. Sadly, the day before this was written, David Packard, Barney's colleague, and also a major contributor to the SETI effort, passed away. It is my hope that this reprint will help carry their pioneering work to its successful conclusion.

Richard Factor
President
The SETI League, Inc.

27 March 1996

Like most other SETI professionals of my generation, I cut my teeth on the Cyclops report. A quarter of a century ago, the giants of radio astronomy designed (on paper) the greatest SETI receiving station never built. One result of the Cyclops Summer was that it taught many of us how to tackle the problem of interstellar communications. Another is that it taught us how to dream.

Many of us who were then watching from the wings have inherited the mantle of responsibility from the Project Cyclops team. As the technology has advanced, we have learned to tackle a few of the engineering problems a bit differently. But though the tools evolve, the nature of SETI has changed precious little in the intervening years. Some studies (such as The SETI League's *Project Argus* sky survey, which I am privileged to head) are using considerably smaller antennas than had been envisioned by the Cyclops team. We choose to make up in digital signal processing power and integration time what we lose in capture area. But even the *Argus* effort retains a crucial ingredient of the Cyclops design: a multitude of antenna elements, working together as a coordinated whole. The underlying strategy of Cyclops stands the test of time. It is still sound.

Today, the youngsters of SETI (among whom I count myself) are all fifty-something, and I worry about how the world will attract its next generation of SETIzens. SETI, after all, is both a highly interdisciplinary endeavor and a multi-generational one, offering much promise for humanity, but little reward for those who demand instant gratification. What blueprint can we pass on to tomorrow's SETI professionals, what guidance can we offer them for applying tomorrow's technology to humankind's oldest dream? I know of no better legacy to pass on than the one given to me and my contemporaries: this Project Cyclops report. Though it has long been out of print, its ink and impact have never faded.

H. Paul Shuch
Executive Director
The SETI League, Inc.

27 March 1996

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With the exception of this title page, and the additions listed below, what follows is the complete facsimile text of the original edition.

Additions to the Second Printing

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Robert S. Dixon	Ohio State University
Johnson Luh	Purdue University
Francis Yu	Wayne State University

ERRATA

page 7: In Figure 2-2, the units of the x axis were omitted. The correct unit is 10^9 years.

page 53: Halfway down the right-hand column, 0.088 / pc^3 should read 0.0188 / pc^3.

page 54: In equation (3), the limits of integration (shown as – to + infinity) should be –R to +R.
The minus sign under the first radical should be a plus sign.
Log [for common logarithm] should read ln [for natural logarithm].

page 55: In equation (5) and the prior paragraph, θ refers to the half-angle of total beamwidth.

page 194: Equation (D43) should read $\sigma_0 = P_0 \, (\mu / n)^{1/2}$.

ACKNOWLEDGEMENTS

These errata were contributed by Bernard M. Oliver, Jill Tarter, Larry Lesyna, and H. Paul Shuch.

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