Project SEESAW (U)

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STUDY S-307

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PROJECT SEESAW (U)

Harold W. Lewis, *Chairman*
Robert E. LeLevier
Arnold Nordsieck
Andrew M. Sessler
Kenneth M. Watson
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CONTENTS

I. PURVIEW

(U) ~~(S)~~ The panel* took as its domain the present state of theory and experiment on physical problems relevant to the program and paid no attention to matters of engineering or systems design. These latter problems have been dealt with by other panels and may indeed be the most difficult questions in an analysis of the potential of the program. The panel considered only the question of whether one can, on scientific grounds, exclude the possibility of developing weapons system based on the SEESAW concept, and then analyzing the scientific program in these terms. It will be seen that the answers are incomplete.

II. OUTLOOK

~~(S)~~ In this program the theoretical achievements have long been ahead of the experimental achievements. The main uncertainties are in the areas of single-pulse survivability, hole-boring, and instabilities. In the latter the streaming and hose instabilities have received the most attention, though the sausage instability may also be relevant. Only in the case of the hose instability for a continuous beam has there been any quantitative experimental verification of the theory and there are still unexplained discrepancies in this simplest situation. Some semiquantitative information on the onset of the streaming instability has also been obtained. Since the proposed system configuration is so much more complicated than even the theory has been able

*In the fall of 1967, the Acting Director of ARPA asked JASON to convene a panel to make comments and recommendations about the progress of Project SEESAW.

to treat well, and a fortiori beyond existing experimental verification, we cannot with confidence say anything about the possible ultimate utility of the system as a weapon. We are sorry that the experimental program is now at a standstill, due to the extensive modifications of the Astron accelerator now in progress at Livermore, and our recommendation will be in the direction of reactivating it.

III. THEORETICAL AND EXPERIMENTAL SITUATION

~~(S)~~ The theories of single-pulse survivability and of the hole-boring process have been carried rather far for an unmodulated beam, though problems associated with the structure of the plasma channel still remain unsolved. The experimental equipment currently available to this program does not have sufficient power to permit an exploration of any of these questions.

~~(S)~~ The theories of the hose, streaming, and sausage instabilities have been carried to a high degree of sophistication, both for the modulated and unmodulated beam, though the structure of the plasma channel assumed in these calculations is somewhat idealized. Experiments at Livermore have demonstrated the existence of the hose instability for an unmodulated beam, and have produced semiquantitative agreement between theory and experiment for this case. The experiments have probably also demonstrated the existence of the streaming instability, though nothing quantitative is known here. Such other matters as mode mixing, nonlinearily, and the interplay among the various instabilities (as, for example, when the streaming instability induces the ionized plasma channel within which the hose instability is developed, as in the Livermore experiments) have received only minor theoretical attention and no experimental attention. Computer modeling efforts to bring these matters together, primarily by Brueckner, are still in an early stage of development.

IV. RELEVANT EXPERIMENTAL FACILITIES

~~(S)~~ The major experimental facility associated with this program has been from the beginning the electron injector for the Astron machine at Livermore, developed for the AEC for other reasons. The SEESAW experiments have been riding on this facility, which has saved money for both parties. The facility is not now active, though preparations for its reactivation are in progress.

~~(S)~~ We have also recently become aware of a class of higher current machines (of which we have had the most detailed contact with those made by Physics International) which produce electron beams of approximately the same energy as the Astron beam, at currents up to 100 times as large. These machines are relatively inexpensive, but probably do not have the same beam quality, although the latter is not entirely clear. These machines were also developed for other reasons, and there is not associated with any of them experimental diagnostic equipment of the quality and diversity of that associated with the Livermore facility. As sources of high current relativistic electron beams, however, we believe this class of machines to have considerable potential for expansion of the SEESAW experimental program.

V. OBSERVATIONS AND RECOMMENDATIONS

~~(S)~~ 1. We believe that the program should be continued. This recommendation is based on the current state of scientific uncertainty which does not permit us to confidently rule out the ultimate feasibility of the weapon system.

~~(S)~~ 2. We recommend that Livermore be pressured to enlarge the theoretical and analytical support to the SEESAW experimental program, which has functioned in the past almost entirely independently of the very considerable theoretical competence available at the Laboratory. We are aware of some of the reasons for this condition, but find it ironic that in this most over-theorized project the experimental program exists almost entirely disjoint from the relevant theoretical community.

~~(S)~~ 3. As has been urged by other panels convened in the mists of antiquity, we also urge that the continued development of a relevant experimental program be given the highest priority. We recommend particularly the development of an experimental program based on the type of machine currently available from Physics International, whether the program is based at Physics International or elsewhere. These machines produce electron beams in the right domain, and it remains only to bring diagnostics to them, or them to diagnostics. We recognize that if ARPA decides to fund a program at Physics International itself, such a program will suffer from lack of previous involvement. In this event, one might consider asking the Stanford Research Institute to monitor such a program, since it has been the seat of much of the theoretical work in the past.

~~(S)~~ 4. We have not considered, and cannot comment upon, the detailed experimental program proposed by the Livermore Laboratory. Because of the time factor, we have not judged this to be the most pressing question before us, but will be happy to undertake such an evaluation separately, if desired.

RADAR PERFORMANCE NOTES FROM LARRY BRENNAN AND JOHN MALLETT

In radars designed for precise tracking and position measurement, range accuracy is generally better than angular accuracy. An angular accuracy of 10^{-4} radians is roughly the best that can be expected at large signal-to-noise ratios (due to gear train or other mechanical errors in dish-type antennas or component tolerances in phased arrays) and at a range of 150 km this corresponds to a 15 meter position error. When accuracy is limited by signal-to-noise ratios, the r.m.s. error in angular position is approximately:

$$\delta x \doteq \frac{\theta R}{\sqrt{S/N}}$$

where θ is beamwidth and R slant range. For a beamwidth of 1° and R of 150 km, $\delta x \doteq 2000/\ S/N$ meters. Range accuracy is proportional to pulse length and is given roughly by

$$\delta R \doteq \frac{c\tau}{2\sqrt{S/N}}$$

where c is the speed of light and τ the pulse length. For a τ of 1/10 microsecond $\delta R \doteq 15/\sqrt{S/N}$ meters. Using pulse compression, pulse lengths of 1/10 microsecond or shorter can be obtained without unreasonable peak power requirements. A slant range accuracy of 1 meter or better can be obtained, neglecting errors due to propagation effects.

A system consisting of three (or more) widely spaced radars could be used for trilateration, each radar measuring slant range to $\sim$ 1 meter. The resulting position accuracy can then be computed from the geometry of the problem, and would be roughly 1 meter for spacings such that the three radar lines of sight are orthogonal. If more than one object is present in the radar measurement volume, there is an association or ghosting problem.

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Security Classification

DOCUMENT CONTROL DATA - R & D

(Security classification of title, body of abstract and indexing annotation must be entered when the overall report is classified)

1. ORIGINATING ACTIVITY (Corporate author) Institute for Defense Analyses	2a. REPORT SECURITY CLASSIFICATION ~~SECRET~~ 2b. GROUP 2

3. REPORT TITLE

Project SEESAW (U)

4. DESCRIPTIVE NOTES (Type of report and inclusive dates)

Study S-307 February 1968

5. AUTHOR(S) (First name, middle initial, last name)

Harold W. Lewis, Robert E. LeLevier, Arnold Nordsieck, Andrew M. Sessler, Kenneth M. Watson, Steven Weinberg

6. REPORT DATE February 1968	7a. TOTAL NO. OF PAGES 5	7b. NO. OF REFS -

8a. CONTRACT OR GRANT NO. DAHC15 C 67 0011 b. PROJECT NO. c. d.	9a. ORIGINATOR'S REPORT NUMBER(S) Study S-307 9b. OTHER REPORT NO(S) (Any other numbers that may be assigned this report) NA

10. DISTRIBUTION STATEMENT In addition to security requirements which apply to this document and must be met, it may be further distributed by the holder only with specific prior approval of ARPA/TIO.

11. SUPPLEMENTARY NOTES NA	12. SPONSORING MILITARY ACTIVITY NA

13. ABSTRACT

(U) This study reports on a review of the status of theory and experiment relevant to Project SEESAW and makes observations and recommendations about continued work in these two areas.

DD FORM 1 NOV 65 1473

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14. KEY WORDS	LINK A		LINK B		LINK C	
	ROLE	WT	ROLE	WT	ROLE	WT

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