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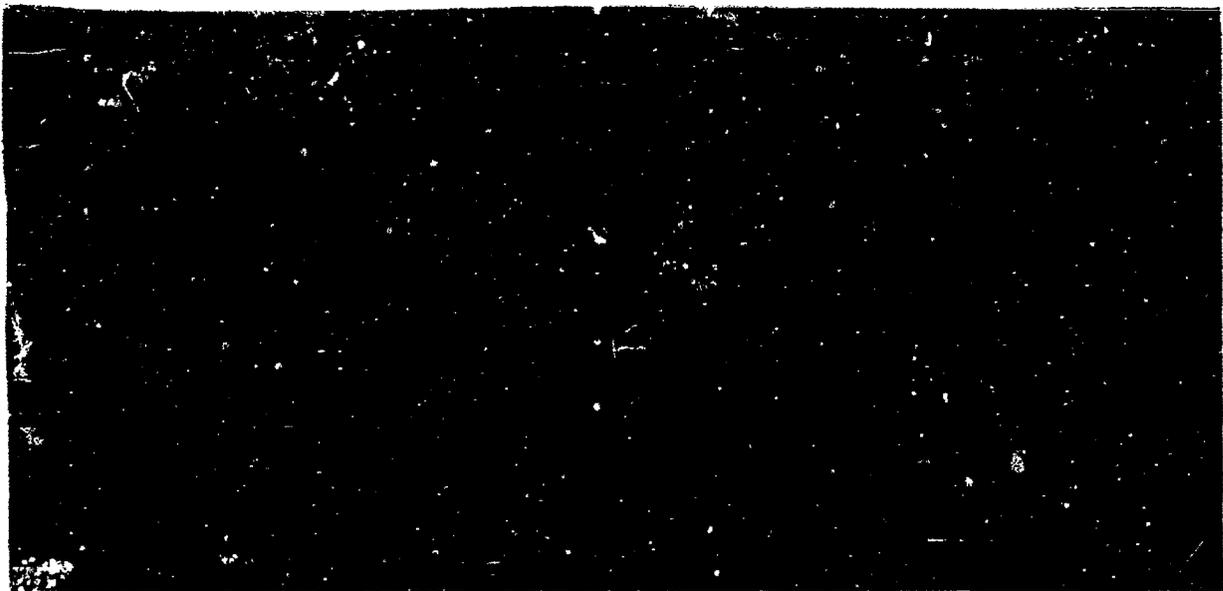
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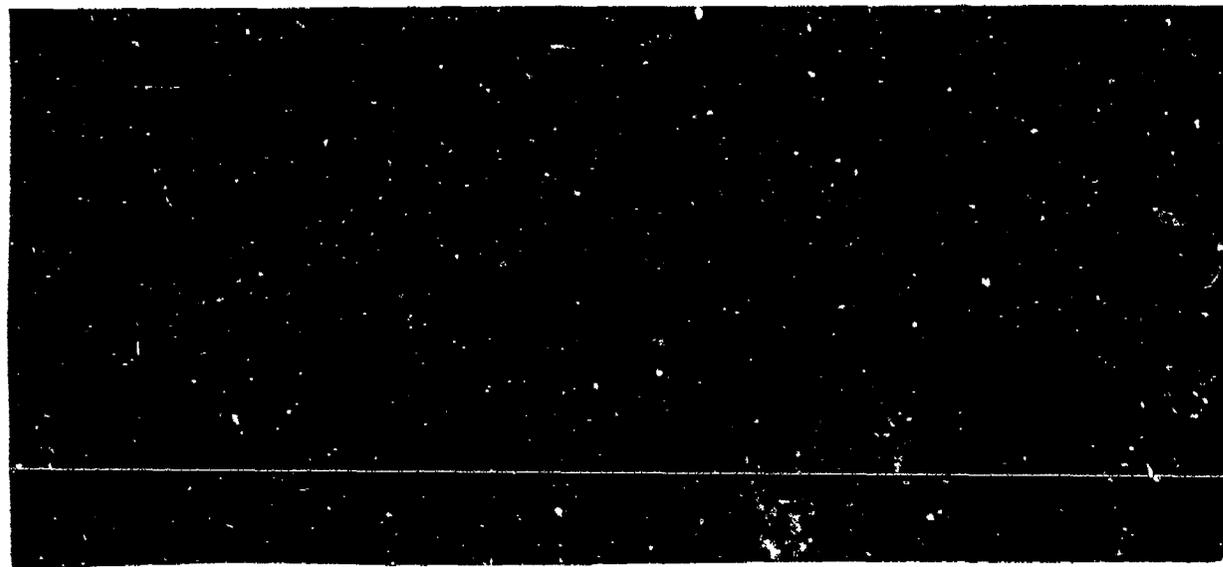
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FEASIBILITY STUDY OF AERIAL PICKUP SYSTEMS

Office of Naval Research Contract Nonr-1279(00)  
Project NR 221-003

This document has been reviewed in accordance with  
OPNAVINST 5510.17, paragraph 5. The security  
classification assigned hereto is correct.

Date: 9/24/54 J. C. Christian  
By direction of  
Chief of Naval Research (Code 461)

Morphological Investigation  
of  
Aerial Pickup Systems  
Involving Fixed Wing Aircraft  
by  
P. S. Chase

September 30, 1953

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ABSTRACT

A systematic investigation has been made of the possible solutions to the problem of in-flight pickup of an object from the ground with fixed wing aircraft. A morphological approach is used to study this problem, since it provides an orderly means of searching for possible solutions. Pertinent features of the various systems which have evolved are discussed briefly.

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Introduction

During and prior to World War II, several systems of aerial pick-up for cargo, gliders, and human subjects were developed to operational capability. These systems were of the type in which a fixed wing aircraft engaged the harness equipment of an object with a boom-stabilized line, and jerked it into the air while limiting the acceleration by cable pay-out or elasticity. Although the feasibility of these systems was demonstrated, this type of operation was not considered entirely adequate by the military for air rescue and other operations uses. Limitations to the versatility of this type of pickup in rescue operations are the following:

- A. Conditions of good visibility are desirable.
- B. A large clear area is required.
- C. Hazard is involved to subject by virtue of close proximity to aircraft at the instant of contact.
- D. Hazard is involved to aircraft due to proximity to surface.
- E. Ground equipment is necessary for subject as well as special equipment for the aircraft.
- F. Pilot technique is involved.
- G. High acceleration loading is imposed on subject.

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A more desirable system would minimize the previous objections and yet allow the use of service aircraft with minimum maneuvering speeds of 150 knots. Thus the high speed and relatively long range capabilities of such aircraft can be utilized. Helicopter, blimp, and convert-to-plane possibilities are excluded from consideration in this study.

Objective

It was the purpose of this investigation to conduct a systematic survey of all the possible solutions to the problem of aerial pickup by fixed wing aircraft in order to generate new ideas for consideration as to feasibility. The scope of the investigation has been limited somewhat by considering systems in accordance with a schedule of desirability which was established after consideration of the problem. This limitation was necessary in order to investigate systems of greatest promise and to restrict the amount of time and effort that would be involved in making a completely generalized study.

Method

The method used is one which has been described as the "Morphological Method"\* by Dr. F. Zwicky of the California Institute of Technology. It consists of determining the fundamental parameters affecting a given problem, tabulating these in matrix form, and examining all combinations and permutations of these parameters for possible solutions. If the parameters are properly chosen, no solution will have been overlooked

\*Described more fully in Ref. 1

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and there will be no duplication. The details of possible schemes are not automatically revealed and considerable inventive genius may be required to discover them. It is usually possible to immediately eliminate many combinations due to impracticality or the boundary conditions on the problem.

In the present investigation, the significant parameters appear to be the following in descending order of importance:

1. Number of aircraft or auxiliary guided devices in the system
  - a. One airplane, or one plane and paravane, or unguided device, (A<sub>1</sub>)
  - b. One airplane and attached auxiliary (guided or homing) device, (A<sub>2</sub>)
  - c. Two airplanes, (A<sub>3</sub>)
2. Character of equipment available to the subject on contact pass
  - a. No equipment, (B<sub>1</sub>)
  - b. Short reach - poles, harness, etc., (B<sub>2</sub>)
  - c. Anchored low altitude reach, (B<sub>3</sub>)
  - d. Free floating or unanchored propelled equipment, (B<sub>4</sub>)
3. Number of passes required to accomplish the pickup operation
  - a. One, (C<sub>1</sub>)
  - b. Two, (C<sub>2</sub>)
  - c. Continuous (circling), etc., (C<sub>3</sub>)

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4. Character of equipment attached to the aircraft
  - a. Zero reach, boom, fork, or boom and pay-out, (D<sub>1</sub>)
  - b. Short line (hundreds ft.), (D<sub>2</sub>)
  - c. Long line (thousands ft.), (D<sub>3</sub>)
5. Duration of opportunity to contact on the contact pass
  - a. Instantaneous, (E<sub>1</sub>)
  - b. Limited, (E<sub>2</sub>)
  - c. Continuous, (E<sub>3</sub>)

Each item has been labeled as shown for convenience in future reference. The totality of combinations or solutions such as A<sub>1</sub>, B<sub>3</sub>, C<sub>2</sub>, D<sub>1</sub>, E<sub>2</sub>, arising from the matrix, is  $3 \times 4 \times 3 \times 3 \times 3 = 324$ .

In order to limit the study to the most productive area, it is necessary to establish an order of preference for the types of systems to be investigated. In this regard, it would appear that if a successful pickup system could be developed without resorting to the use of more than one aircraft, (A<sub>3</sub>), or free floating or unanchored self-propelled equipment for the subject, (B<sub>4</sub>), it would be most desirable. In addition the possibility of improving the restricted visibility or all weather capabilities of the pickup scheme would be greatly increased, since formation or precision flying, which would be required of these multiple systems would be eliminated and communication problems would be

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minimized. A single aircraft is also a smaller visual, radar, or acoustic target. In order of preference, the remaining vehicle combinations are single aircraft and next, single aircraft plus attached homing or guided device.

Of second importance is the equipment available to the subject on contact pass, since this equipment fixes the requirements on the rest of the system. It is most advantageous from an operational standpoint to limit the extent and complexity of the equipment which the subject initially must have in his possession. However, considering the single aircraft systems and in cases of restricted visibility conditions, a fairly elaborate rig can be dropped to him on the first pass, since multiplicity of passes becomes less objectionable. Under these conditions, the visibility of this rig, time to assemble it, and duration of its exposure, all assume less important roles than might otherwise be the case.

The number of passes involved in the pickup is of next importance, since the possibility of detection of the subject or the aircraft increases in proportion to the number of passes. Again, however, the possibility of restricted visibility operation minimizes the importance of this factor. Repeated pass systems, however, generally imply pinpoint relocation of the subject or his equipment with the attendant complications.

Of fourth importance is the aircraft equipment, since this factor is more susceptible to control in the design stages.

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The duration of opportunity to make contact is primarily of importance in the amount of training and skill of personnel involved and in increasing the possibility of contact under adverse conditions due to weather, visibility, terrain, etc.

In view of the foregoing arguments, it would appear that systems involving one aircraft and no equipment for the subject are most desirable. The order of preference of arrangements beneath this maximum is as follows:

1. One plane, no subject equipment, one pass
2. " " " " " two passes
3. " " " " " continuous (circling)
4. " " short reach subject equipment, one pass
5. " " " " " " two passes
6. " " " " " " continuous (circling)
7. " " anchored low altitude reach subject equipment, one pass
8. " " " " " " " " two passes
9. " " " " " " " " continuous (circling)
10. " " and auxiliary guided or homing device, no subject equipment, one pass
11. " " " " " " " " " " two passes
12. " " " " " " " " " " continuous (circling)

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13. One plane and auxiliary guided or homing device, short reach subject equipment, one pass
14. One plane and auxiliary guided or homing device, short reach subject equipment, two passes
15. One plane and auxiliary guided or homing device, short reach subject equipment, continuous (circling)
16. One plane and auxiliary guided or homing device, anchored low altitude reach subject equipment, one pass
17. One plane and auxiliary guided or homing device, anchored low altitude reach subject equipment, two passes
18. One plane and auxiliary guided or homing device, anchored low altitude reach subject equipment, continuous (circling)

Of these major combinations, each has 9 variations possible in the plane's equipment and the opportunity to contact. This makes up a total of 162 possibilities, although it will be shown that 54 of these are superfluous and only 108 solutions remain. These possibilities will be considered individually for solutions.

Results

Previously existing or proposed schemes are diagrammatically represented in Appendix I. Details of these schemes are described in Refs. 2 through 7. It is shown where the majority of these arise in the matrix and additional suggestions are presented in Appendix II.

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<u>System</u>	<u>Solution</u>
1. A <sub>1</sub> B <sub>1</sub> C <sub>1</sub> D <sub>1</sub> E <sub>1</sub>	None Obvious
A <sub>1</sub> B <sub>1</sub> C <sub>1</sub> D <sub>1</sub> E <sub>2</sub>	None Obvious
A <sub>1</sub> B <sub>1</sub> C <sub>1</sub> D <sub>1</sub> E <sub>3</sub>	Not Possible
A <sub>1</sub> B <sub>1</sub> C <sub>1</sub> D <sub>2</sub> E <sub>1</sub>	None Obvious
A <sub>1</sub> B <sub>1</sub> C <sub>1</sub> D <sub>2</sub> E <sub>2</sub>	None Obvious
A <sub>1</sub> B <sub>1</sub> C <sub>1</sub> D <sub>2</sub> E <sub>3</sub>	Not Possible
A <sub>1</sub> B <sub>1</sub> C <sub>1</sub> D <sub>3</sub> E <sub>1</sub>	None Obvious
A <sub>1</sub> B <sub>1</sub> C <sub>1</sub> D <sub>3</sub> E <sub>2</sub>	All American Engineering Proposal #6 or North American Instruments Idea #1
A <sub>1</sub> B <sub>1</sub> C <sub>1</sub> D <sub>3</sub> E <sub>3</sub>	Not Possible
2. Systems A <sub>1</sub> B <sub>1</sub> C <sub>2</sub>	involving no equipment for subject do not apparently benefit from two pass systems and will not be considered.
3. A <sub>1</sub> B <sub>1</sub> C <sub>3</sub> D <sub>1</sub> E <sub>1</sub>	None Obvious
A <sub>1</sub> B <sub>1</sub> C <sub>3</sub> D <sub>1</sub> E <sub>2</sub>	None Obvious
A <sub>1</sub> B <sub>1</sub> C <sub>3</sub> D <sub>1</sub> E <sub>3</sub>	None Obvious
A <sub>1</sub> B <sub>1</sub> C <sub>3</sub> D <sub>2</sub> E <sub>1</sub>	None Obvious
A <sub>1</sub> B <sub>1</sub> C <sub>3</sub> D <sub>2</sub> E <sub>2</sub>	None Obvious
A <sub>1</sub> B <sub>1</sub> C <sub>3</sub> D <sub>2</sub> E <sub>3</sub>	None Obvious

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3.  $A_1 B_1 C_2 D_2 E_1$  None Obvious  
 $A_1 B_1 C_2 D_2 E_2$  NAI Idea #1, with line pay-out and upward spiral by aircraft  
 $A_1 B_1 C_2 D_2 E_3$  Failure "Hope Trick", AAE Proposal #18, NAI Ideas #8 and #2

4. Systems  $A_1, B_2, C_1$ , involving short reach subject equipment, and other means subject can obtain necessary equipment himself or have it dropped to him on first pass. Thus, if the general case is assumed, single pass systems of this type have identical solutions to those of two pass systems  $A_1 B_2 C_2$  below.

5.  $A_1 B_2 C_2 D_1 E_1$  Standard AAE Technique, or AAE Proposal #4, 5, 14  
 $A_1 B_2 C_2 D_1 E_2$  None Obvious  
 $A_1 B_2 C_2 D_1 E_3$  Not Feasible  
 $A_1 B_2 C_2 D_2 E_1$  NAI Idea #4  
 $A_1 B_2 C_2 D_2 E_2$  None Obvious  
 $A_1 B_2 C_2 D_2 E_3$  Not Feasible  
 $A_1 B_2 C_2 D_3 E_1$  NAI Idea #4 with long line  
 $A_1 B_2 C_2 D_3 E_2$  NAI Idea #1 with increase, etc. dropped on first pass  
 $A_1 B_2 C_2 D_3 E_3$  Not Feasible

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|----|----------------------------------------------------------------------------|---------------------------------------------------------------------------------------|
| 6. | A <sub>1</sub> B <sub>2</sub> C <sub>3</sub> D <sub>1</sub> E <sub>1</sub> | None Obvious                                                                          |
|    | A <sub>1</sub> B <sub>2</sub> C <sub>3</sub> D <sub>1</sub> E <sub>2</sub> | None Obvious                                                                          |
|    | A <sub>1</sub> B <sub>2</sub> C <sub>3</sub> D <sub>1</sub> E <sub>3</sub> | None Obvious                                                                          |
|    | A <sub>1</sub> B <sub>2</sub> C <sub>3</sub> D <sub>2</sub> E <sub>1</sub> | None Obvious                                                                          |
|    | A <sub>1</sub> B <sub>2</sub> C <sub>3</sub> D <sub>2</sub> E <sub>2</sub> | None Obvious                                                                          |
|    | A <sub>1</sub> B <sub>2</sub> C <sub>3</sub> D <sub>2</sub> E <sub>3</sub> | None Obvious                                                                          |
|    | A <sub>1</sub> B <sub>2</sub> C <sub>3</sub> D <sub>3</sub> E <sub>1</sub> | None Obvious                                                                          |
|    | A <sub>1</sub> B <sub>2</sub> C <sub>3</sub> D <sub>3</sub> E <sub>2</sub> | NAI Idea #1 with spiral pull out and harness dropped on first pass, or NAI Idea #6    |
|    | A <sub>1</sub> B <sub>2</sub> C <sub>3</sub> D <sub>3</sub> E <sub>3</sub> | AAE Proposal #10, Fulton "Rope Trick", NAI Idea #2 with harness dropped on first pass |

7. Since subject cannot be expected to have equipment for anchored low altitude reach available without dropping it to him, one pass systems, A<sub>1</sub> B<sub>3</sub> C<sub>1</sub>, will not be considered.

- |    |                                                                            |                                                                    |
|----|----------------------------------------------------------------------------|--------------------------------------------------------------------|
| 8. | A <sub>1</sub> B <sub>3</sub> C <sub>2</sub> D <sub>1</sub> E <sub>1</sub> | Fulton "Skyhook", AAE Proposals #7, 9, 11, 12, and 13, NAI Idea #6 |
|    | A <sub>1</sub> B <sub>3</sub> C <sub>2</sub> D <sub>1</sub> E <sub>2</sub> | None Obvious                                                       |
|    | A <sub>1</sub> B <sub>3</sub> C <sub>2</sub> D <sub>1</sub> E <sub>3</sub> | Impossible                                                         |
|    | A <sub>1</sub> B <sub>3</sub> C <sub>2</sub> D <sub>2</sub> E <sub>1</sub> | Modified AAE Standard Technique                                    |
|    | A <sub>1</sub> B <sub>3</sub> C <sub>2</sub> D <sub>2</sub> E <sub>2</sub> | NAI Idea #7                                                        |

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|-----|----------------------------------------------------------------------------|---------------------------------|
| 8.  | A <sub>1</sub> B <sub>3</sub> C <sub>2</sub> D <sub>2</sub> E <sub>3</sub> | Impossible                      |
|     | A <sub>1</sub> B <sub>3</sub> C <sub>2</sub> D <sub>3</sub> E <sub>1</sub> | Modified AAE Standard Technique |
|     | A <sub>1</sub> B <sub>3</sub> C <sub>2</sub> D <sub>3</sub> E <sub>2</sub> | NAI Idea #7                     |
|     | A <sub>1</sub> B <sub>3</sub> C <sub>2</sub> D <sub>3</sub> E <sub>3</sub> | Impossible                      |
| 9.  | A <sub>1</sub> B <sub>3</sub> C <sub>3</sub> D <sub>1</sub> E <sub>1</sub> | None Obvious                    |
|     | A <sub>1</sub> B <sub>3</sub> C <sub>3</sub> D <sub>1</sub> E <sub>2</sub> | None Obvious                    |
|     | A <sub>1</sub> B <sub>3</sub> C <sub>3</sub> D <sub>1</sub> E <sub>3</sub> | NAI Idea #8                     |
|     | A <sub>1</sub> B <sub>3</sub> C <sub>3</sub> D <sub>2</sub> E <sub>1</sub> | None Obvious                    |
|     | A <sub>1</sub> B <sub>3</sub> C <sub>3</sub> D <sub>2</sub> E <sub>2</sub> | None Obvious                    |
|     | A <sub>1</sub> B <sub>3</sub> C <sub>3</sub> D <sub>2</sub> E <sub>3</sub> | NAI Idea #6                     |
|     | A <sub>1</sub> B <sub>3</sub> C <sub>3</sub> D <sub>3</sub> E <sub>1</sub> | None Obvious                    |
|     | A <sub>1</sub> B <sub>3</sub> C <sub>3</sub> D <sub>3</sub> E <sub>2</sub> | None Obvious                    |
|     | A <sub>1</sub> B <sub>3</sub> C <sub>3</sub> D <sub>3</sub> E <sub>3</sub> | None Obvious                    |
| 10. | A <sub>2</sub> B <sub>1</sub> C <sub>1</sub> D <sub>1</sub> E <sub>1</sub> | None Obvious                    |
|     | A <sub>2</sub> B <sub>1</sub> C <sub>1</sub> D <sub>1</sub> E <sub>2</sub> | None Obvious                    |
|     | A <sub>2</sub> B <sub>1</sub> C <sub>1</sub> D <sub>1</sub> E <sub>3</sub> | Impossible                      |
|     | A <sub>2</sub> B <sub>1</sub> C <sub>1</sub> D <sub>2</sub> E <sub>1</sub> | None Obvious                    |
|     | A <sub>2</sub> B <sub>1</sub> C <sub>1</sub> D <sub>2</sub> E <sub>2</sub> | None Obvious                    |
|     | A <sub>2</sub> B <sub>1</sub> C <sub>1</sub> D <sub>2</sub> E <sub>3</sub> | None Obvious                    |

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10.  $A_2 B_1 C_1 D_3 E_1$  None Obvious  
 $A_2 B_1 C_1 D_3 E_2$  NAI Idea #9  
 $A_2 B_1 C_1 D_3 E_3$  Impossible
11. Systems  $A_2 B_1 C_2$ , involving no equipment for subject do not make effective use of two passes and these systems are superfluous.
12.  $A_2 B_1 C_3 D_1 E_1$  None Obvious  
 $A_2 B_1 C_3 D_1 E_2$  None Obvious  
 $A_2 B_1 C_3 D_1 E_3$  Impossible  
 $A_2 B_1 C_3 D_2 E_1$  None Obvious  
 $A_2 B_1 C_3 D_2 E_2$  None Obvious  
 $A_2 B_1 C_3 D_2 E_3$  None Obvious  
 $A_2 B_1 C_3 D_3 E_1$  None Obvious  
 $A_2 B_1 C_3 D_3 E_2$  None Obvious  
 $A_2 B_1 C_3 D_3 E_3$  AAE Proposal #1 with one plane and drone, NAI Idea #10
13. One pass systems of the type  $A_2 B_2 C_1$ , are identical to those of 14 below, but assume subject has necessary equipment in his possession originally rather than receiving it by drop on first pass.

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|-----|----------------------------------------------------------------------------|---------------------------------------------------------|
| 14. | A <sub>2</sub> B <sub>2</sub> C <sub>2</sub> D <sub>1</sub> E <sub>1</sub> | None Obvious                                            |
|     | A <sub>2</sub> B <sub>2</sub> C <sub>2</sub> D <sub>1</sub> E <sub>2</sub> | None Obvious                                            |
|     | A <sub>2</sub> B <sub>2</sub> C <sub>2</sub> D <sub>1</sub> E <sub>3</sub> | Impossible                                              |
|     | A <sub>2</sub> B <sub>2</sub> C <sub>2</sub> D <sub>2</sub> E <sub>1</sub> | NAI Idea #11                                            |
|     | A <sub>2</sub> B <sub>2</sub> C <sub>2</sub> D <sub>2</sub> E <sub>2</sub> | None Obvious                                            |
|     | A <sub>2</sub> B <sub>2</sub> C <sub>2</sub> D <sub>2</sub> E <sub>3</sub> | Impossible                                              |
|     | A <sub>2</sub> B <sub>2</sub> C <sub>2</sub> D <sub>3</sub> E <sub>1</sub> | NAI Idea #11                                            |
|     | A <sub>2</sub> B <sub>2</sub> C <sub>2</sub> D <sub>3</sub> E <sub>2</sub> | NAI Idea #9, with target and harness dropped to subject |
|     | A <sub>2</sub> B <sub>2</sub> C <sub>2</sub> D <sub>3</sub> E <sub>3</sub> | Impossible                                              |
| 15. | A <sub>2</sub> B <sub>2</sub> C <sub>3</sub> D <sub>1</sub> E <sub>1</sub> | None Obvious                                            |
|     | A <sub>2</sub> B <sub>2</sub> C <sub>3</sub> D <sub>1</sub> E <sub>2</sub> | None Obvious                                            |
|     | A <sub>2</sub> B <sub>2</sub> C <sub>3</sub> D <sub>1</sub> E <sub>3</sub> | Impossible                                              |
|     | A <sub>2</sub> B <sub>2</sub> C <sub>3</sub> D <sub>2</sub> E <sub>1</sub> | None Obvious                                            |
|     | A <sub>2</sub> B <sub>2</sub> C <sub>3</sub> D <sub>2</sub> E <sub>2</sub> | None Obvious                                            |
|     | A <sub>2</sub> B <sub>2</sub> C <sub>3</sub> D <sub>2</sub> E <sub>3</sub> | NAI Idea #12                                            |
|     | A <sub>2</sub> B <sub>2</sub> C <sub>3</sub> D <sub>3</sub> E <sub>1</sub> | None Obvious                                            |
|     | A <sub>2</sub> B <sub>2</sub> C <sub>3</sub> D <sub>3</sub> E <sub>2</sub> | None Obvious                                            |
|     | A <sub>2</sub> B <sub>2</sub> C <sub>3</sub> D <sub>3</sub> E <sub>3</sub> | AAE Proposal #1 with drone                              |

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16. One pass systems of the type  $A_2 B_3 C_1$ , are superfluous since subject must be dropped necessary equipment on first pass.

- |                           |                      |
|---------------------------|----------------------|
| 17. $A_2 B_3 C_2 D_1 E_1$ | None Obvious         |
| $A_2 B_3 C_2 D_1 E_2$     | None Obvious         |
| $A_2 B_3 C_2 D_1 E_3$     | Impossible           |
| $A_2 B_3 C_2 D_2 E_1$     | NAI Ideas #7, and 13 |
| $A_2 B_3 C_2 D_2 E_2$     | None Obvious         |
| $A_2 B_3 C_2 D_2 E_3$     | Impossible           |
| $A_2 B_3 C_2 D_3 E_1$     | NAI Idea #13         |
| $A_2 B_3 C_2 D_3 E_2$     | None Obvious         |
| $A_2 B_3 C_2 D_3 E_3$     | impossible           |
| 18. $A_2 B_3 C_3 D_1 E_1$ | None Obvious         |
| $A_2 B_3 C_3 D_1 E_2$     | None Obvious         |
| $A_2 B_3 C_3 D_1 E_3$     | Impossible           |
| $A_2 B_3 C_3 D_2 E_1$     | None Obvious         |
| $A_2 B_3 C_3 D_2 E_2$     | None Obvious         |
| $A_2 B_3 C_3 D_2 E_3$     | NAI Idea #14         |
| $A_2 B_3 C_3 D_3 E_1$     | None Obvious         |
| $A_2 B_3 C_3 D_3 E_2$     | None Obvious         |
| $A_2 B_3 C_3 D_3 E_3$     | None Obvious         |

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The results of the morphological study fall into three classes:

- a. Possible new systems
- b. Ideas for modification to or combinations of previously proposed or perfected systems
- c. Ideas for generalized investigation of problems common to many proposed systems

Material in classes (a) and (b) has been discussed in Appendix II.

Ideas in class (c) have arisen as a by-product of the matrix investigation as it became apparent that many systems involved common problems. Among the more important of these are problems of pin-point navigation or homing, importance of cable shape, means of providing more nearly vertical subject rise, and possibility of eliminating the protective capsule for the subject which seems to be generally considered desirable.

In most of the systems proposed, conditions of contact flight must pertain in order to accurately locate the subject. However, it is conceivable that this problem may be very difficult for restricted visibility conditions and low altitude approach systems. The problem of navigating to the general vicinity of the subject is probably not complex but pin-point location of the subject or his equipment in order to make contact must be investigated much more thoroughly. A number of possible solutions to this problem, if accumulated, would broaden the applicability of many of the proposed schemes.

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Although reference literature exists for prediction of cable shapes under conditions of equilibrium, no information is available for dynamic conditions. The change in cable shape from towing a low drag-to-weight ratio homing head to towing a human subject whose drag-to-weight ratio is large may well provide a means for more nearly vertical rise of the subject in systems utilizing relatively long cables and more or less linear aircraft flight.

It is also possible that the dynamics of cable motion due to rapid acceleration, in schemes such as North American Instruments Idea 1, will allow somewhat improved vertical rise over conventional linear flight systems. The use of controlled drag parachutes or paravanes may also be capable of considerably enhancing rates of rise after initial contact. The resistance-to-weight ratio of the cable itself is also an important parameter in this regard.

The use of a capsule to contain the subject and either protect him from exposure to the elements, physical contact with obstacles, or to prevent aerodynamic instability, is worthy of scrutiny in each design considered. The possibility that such precaution is unnecessary in many instances is indicated.

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Discussion

Salient features which should be considered in any pickup system include:

- A. Installation of equipment and training of personnel required
- B. Navigation to general vicinity of target
- C. Pin-point navigation to target
- D. Approach
- E. Contact
- F. Breakaway of subject
- G. Subsequent maneuver of aircraft
- H. Reel-in
- I. Entry into aircraft

Considering the requirements of a desirable system and the factors listed above, the following types of systems are attractive.

It appears that a system involving near vertical emplacement of required equipment and the Falton and All American "Skyhook" or "Rope Trick" type of rise is by far the most desirable, since such systems allow operation in relatively unclear areas and maintain g loads on the subject at a low level. For this reason, light lines with simple harness can be used and the possibility of picking up subjects in poor physical condition is increased. The outstanding problems involved in perfecting a system of this sort and adapting it for restricted visibility conditions involve one or more of the following:

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1. Pin-point location of subject
2. Accurate emplacement of dropped equipment
3. Guidance or homing for actual contact
4. Minimizing line lengths required

These problems do not appear insurmountable. A major disadvantage of such systems, if visibility is restricted, is that the subject initially must possess a beacon or homing target. However, this target might be a very simple radar reflector or a heat source.

A second class of systems of somewhat more limited application would involve the use of a towed homing device on a relatively long cable which would seek the subject's target and pick him up, in a manner somewhat similar to the conventional one already perfected by the All American Engineering Company. The homing device would allow restricted vision operation and minimize danger to the aircraft by allowing it to maintain a reasonable altitude. The length of the line could be between a few hundred and a few thousand feet, and should not present operational problems of too great magnitude. This system, although particularly adaptable to use in relatively clear areas or over water could be combined with the "Skyhook" technique to allow operation in obstructed areas and remove the homing device from proximity to the subject. The same problems are involved in the development of this system as were previously mentioned.

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The use of homing devices for restricted visibility conditions suggests the possibility that a human, if properly equipped, would constitute a homing system of rather high capability. For instance, if a powered minimum complexity aircraft of limited performance were towed on a long line beneath a mother craft, it would allow the pilot of such a craft to dodge obstacles, choose a good landing area and possibly allow almost vertical landing by a technique in which the parasite flies close to the ground in direction opposite to that of the towing craft and gradually sinks to the earth as cable is payed out and it loses relative speed with the atmosphere. Take-off with both passengers could be assisted or accomplished entirely by the mother craft as it climbs in a spiral. It can be seen that this type of operation will not require the parasite to be an airplane of usual complexity but rather a powered glider type of gondola with limited controllability and minimum equipment.

It should be noted that several of the pickup systems proposed will function in the inverse as devices to transfer a human from an aircraft to the ground.

Conclusion

A systematic study of the possible solutions to the problem of aerial pickup by fixed wing aircraft has been outlined. By considering the most desirable solutions according to a somewhat arbitrary priority rating, 108 of these systems have been investigated. Ideas

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for new systems have arisen and several extensions or combinations of already proposed systems have presented themselves. The all weather or restricted visibility application has been held foremost in the analysis.

It is hoped that the systems for which no solution was obvious will offer food for thought for others concerned with this problem. If the effort is warranted, 162 more systems could be analyzed which would involve two airplanes or an airplane and free floating or propelled equipment for the subject. This type of system is quite interesting for certain applications.

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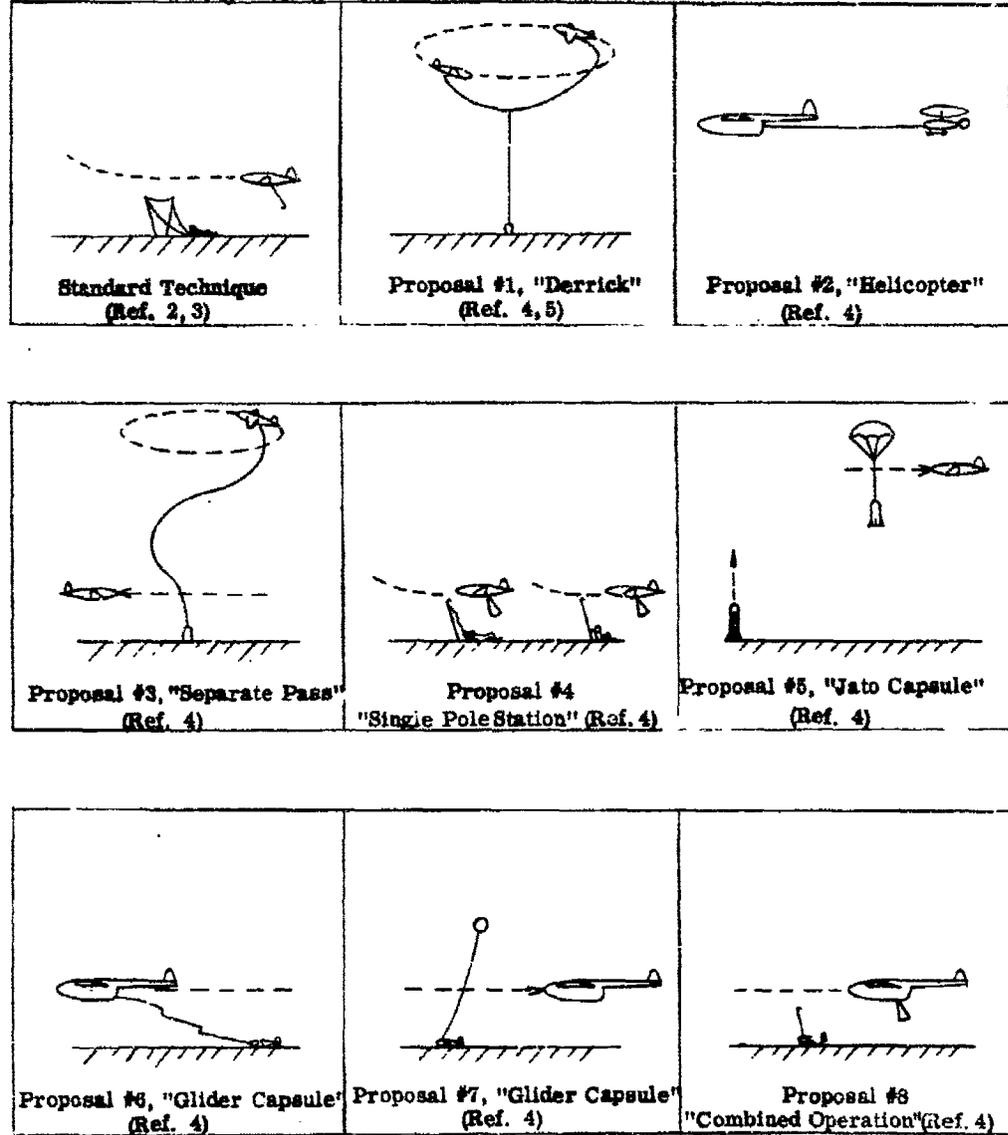
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APPENDIX I

SYSTEMS EXISTING OR PROPOSED

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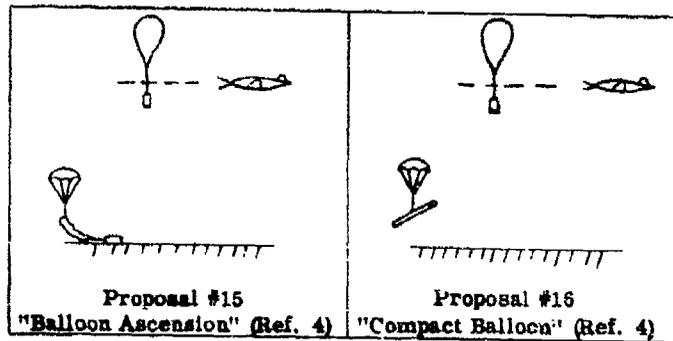
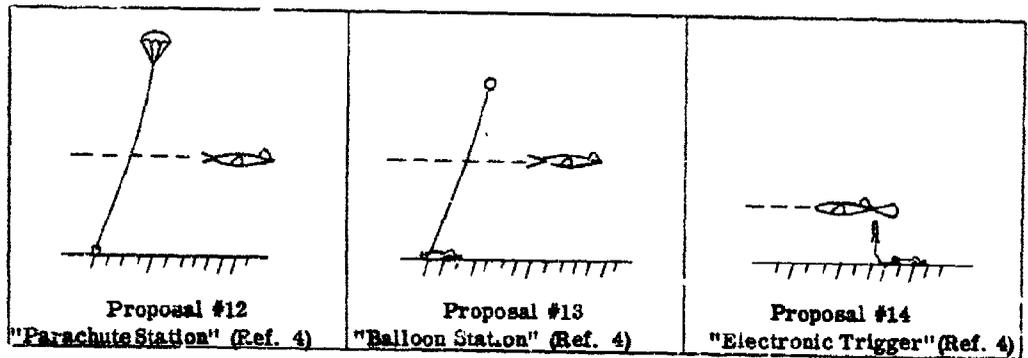
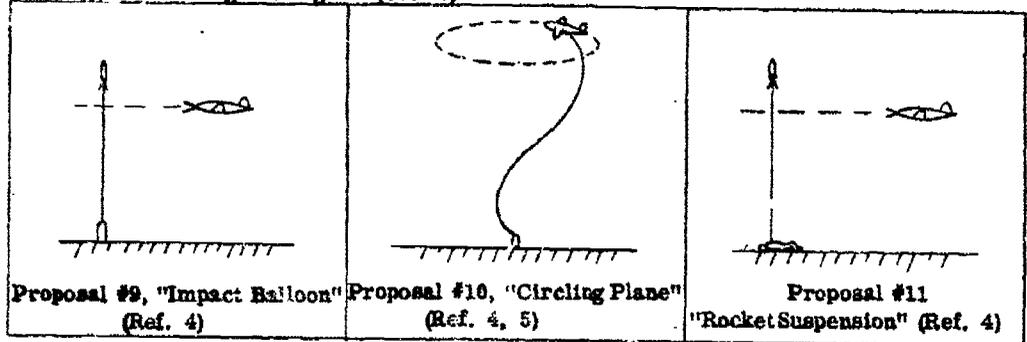


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1. All American Engineering Co. (Cont'd)



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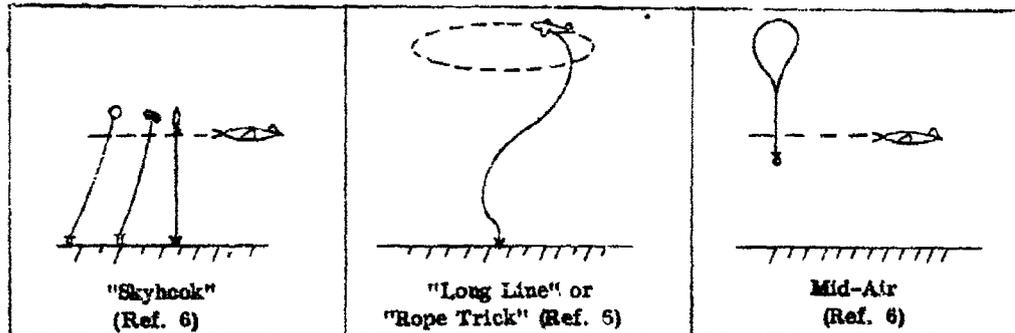
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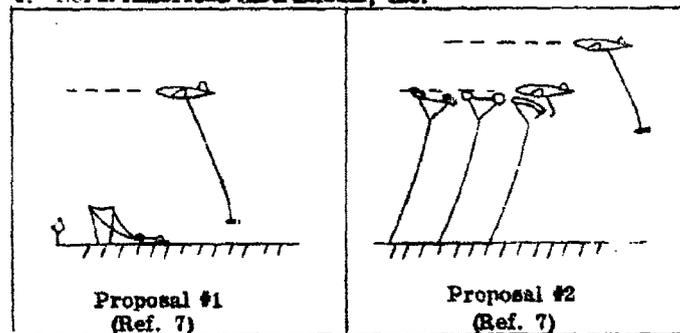
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2. Robert Fulton, Jr.



3. North American Instruments, Inc.



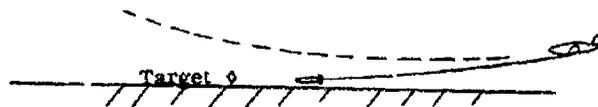
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APPENDIX II

North American Instruments Idea #1



- Class of Idea:** New
- Related Systems:** All American Engineering Proposal #6
- Description:** Rocket fired ahead of aircraft from low altitude at shallow approach angle so as to lay cable on the ground a few thousand feet ahead of the aircraft. Cable jerked off by plane in linear or spiraling flight and thus allows few seconds for subject to attach. Variations include
- (a) firing line beneath subject's pickup loop
  - (b) allowing him to run to the line and make attachment
  - (c) allowing him to manually or otherwise throw a line from his harness across the aircraft line
- Advantages:**
- (a) Existing fire control apparatus, rockets and rocket launchers might be used
  - (b) Could be adapted to restricted vision use by radar or infra-red sight and target near subject
  - (c) Affords linear rather than point attachment opportunity
  - (d) Accurate emplacement possible so subject's run minimized.
  - (e) Line configuration may give fairly vertical rise path

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APPENDIX II  
(Cont'd)

North American Instruments Idea #1 (Cont'd)

Disadvantages:

- (a) Long Line
- (b) Very short opportunity to attach
- (c) Probably involves high loading on subject and may require wearing harness
- (d) Requires large cleared area
- (e) Target required near subject if radar or infra-red sight used.

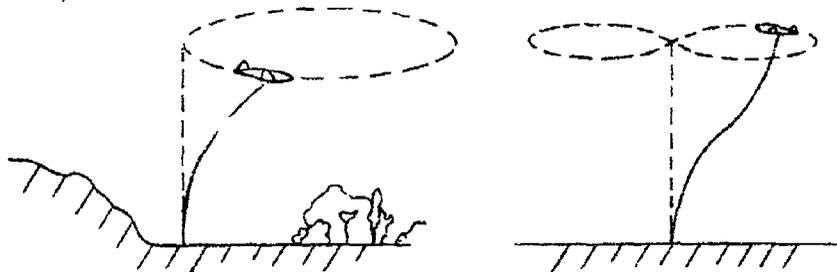
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APPENDIX II  
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North American Instruments Idea #2



**Class of Idea:** Extension

**Related Systems:** AAE Proposals #3, 1J, and Fulton "Rope Trick"

**Description:** Plane describes horizontal circle or figure eight at low altitude with one end of a relatively long line staked in the ground by technique as described in KAI Idea #3 until attachment with subject is made; a re-wind attachment in the cable reel removes slack whenever required. Actual pickup is accomplished when aircraft is directly over the subject by clamping the cable over the drum to fix its length and assure most vertical subject rise possible.

**Advantages:**

- (a) Minimum line length maintained at all times
- (b) Little pilot technique involved
- (c) Continuous attachment opportunity presented
- (d) Possibility of fairly vertical Fulton-type rise due to clamping cable at instant of pickup
- (e) Restricted visibility operation possible
- (f) No large clear area required

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APPENDIX II  
(Cont'd)

North American Instruments Idea #2 (Cont'd)

Disadvantages:

- (a) The long line
- (b) More complex reel mechanism
- (c) Cable diameter might be larger than for other long time techniques because of larger g loading.

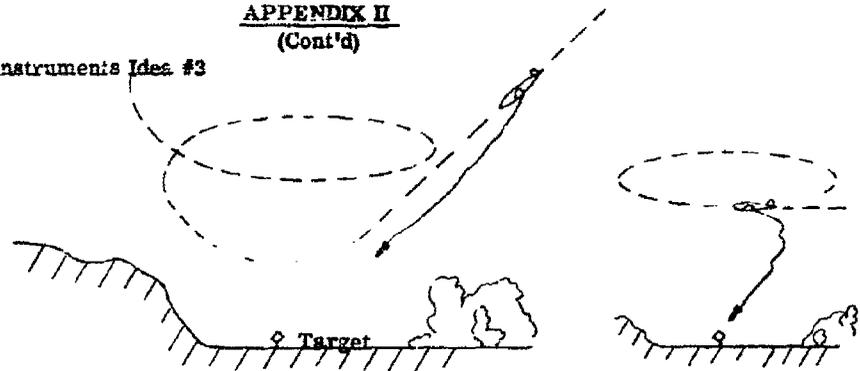
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APPENDIX II  
(Cont'd)

North American Instruments Idea #3



**Class of Idea:** Extension

**Related Systems:** AAE Proposals #3, 10, Fulton "Rope Trick"

**Description:** The long line type of operation could be modified to enable accurate cable staking by use of a dive bombing technique and subsequent upward spiraling maneuver, allowing the subject to attach himself to harness on cable near anchor point. The dive bombing technique is accurate but would be useful only under conditions of good visibility. A modified system useful under restricted visibility conditions would involve a horizontal bombing technique from relatively low altitude with radar or infra-red bombsight.

**Advantages:**

- (a) All advantages of the long line technique
- (b) Restricted vision operation possible
- (c) No equipment necessary for subject except target if visibility restricted
- (d) Accurate anchor emplacement

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APPENDIX II  
(Cont'd)

North American Instruments Idea #3 (Cont'd)

Disadvantages:

- (a) Long line
- (b) Existing bombights may be inadequate
- (c) Development problem in ballistics of bomb-type anchor with cable attached.

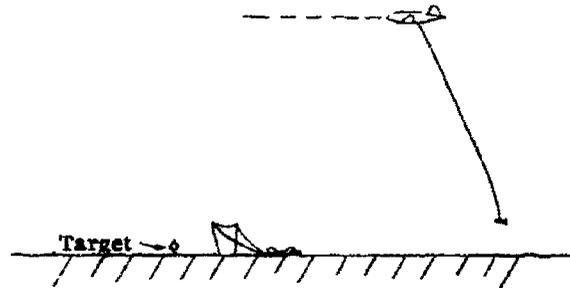
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North American Instruments Idea #4



- Class of Idea:** Extension
- Related Systems:** Standard AAE Technique, AAE Proposals #4, 8, and NAI Proposal #1.
- Description:** A modification of the Standard AAE Technique incorporating a short line with an airfoil type paravane attached to allow aircraft to operate at less proximity to ground. The ground effect should present a useful aerodynamic force to maintain constant altitude of the paravane above the surface, thus decreasing pilot technique involved. This system might be applicable to pickup off of water or large cleared areas under some conditions of restricted visibility.
- Advantages:**
- (a) Greater aircraft safety
  - (b) Possible restricted vision application
  - (c) Pilot technique minimized, since paravane controls height of pickup hook

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APPENDIX II  
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North American Instruments Idea #4 (Cont'd)

Disadvantages:

- (a) Visual aiming might be more difficult than conventional system
- (b) Paravane is hazard to the subject
- (c) High "g" loading involved.

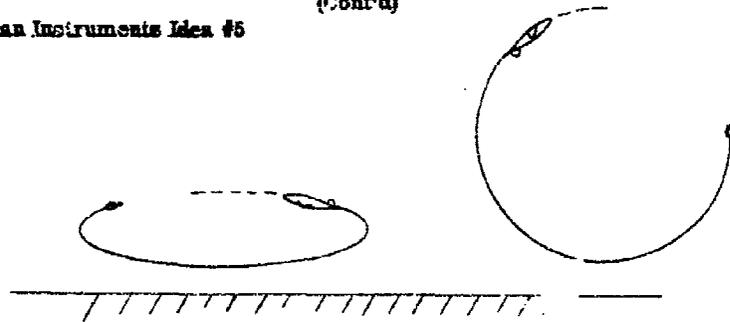
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APPENDIX II  
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North American Instruments Idea #5



**Class of Idea:** New

**Related Systems:** None

**Description:** It might be possible for a single aircraft to fly in a horizontal circle or a vertical loop and, towing a long line with proper paravane or drone, maintain this line in a circular pattern, so that the subject's gear could be attached to it in the same manner that something would be attached to a clothesline. This system has obvious difficulties and does not appear practical.

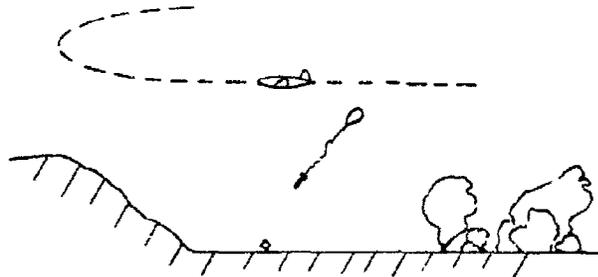
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North American Instruments Idea #6



**Class of Idea:** Extension

**Related Systems:** AAE Proposals #7, 12, 13, 15, 16, Fulton "Skyhook", and NAI Proposal #2.

**Description:** This system would involve dropping on the first pass a short length of cable with an anchor on one end and an inflated or inflating balloon capable of supporting the cable on the other. This assembly would then be ready to operate immediately upon anchoring itself, except for the time required by the subject to enter the attached harness. On the second pass, a very short time later, the actual pickup could be made by fork, boom, or systems described in NAI Idea #7.

**Advantages:** (a) Accurate emplacement of the anchor and "Skyhook" could probably be made even under conditions of restricted visibility.

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APPENDIX II  
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North American Instruments Idea #6 (Cont'd)

Advantages:  
(Cont'd)

- (b) No equipment necessary for subject other than target if visibility is restricted
- (c) No assembly of equipment necessary for subject
- (d) Low g loading on subject with near vertical rise
- (e) Little pilot technique involved

Disadvantages:

- (a) It is necessary to accurately locate subject or his equipment twice.
- (b) Dropping inflated or inflating balloon will involve an additional development problem.

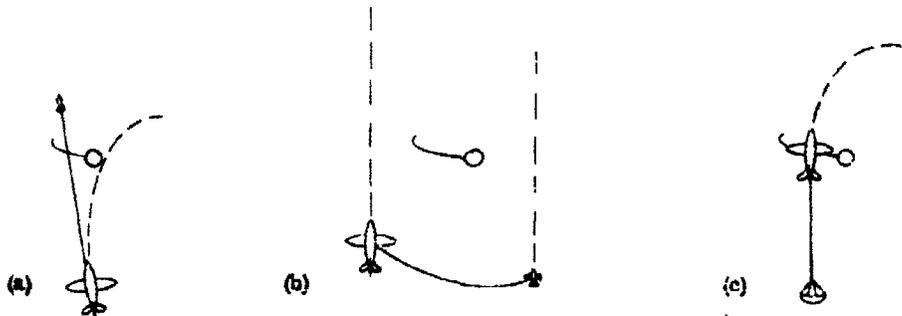
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North American Instruments Idea #7



**Class of Idea:** Extension

**Related Systems:** AAE Proposals #7, 9, 11, 12, 13, Fulton "Skyhook", and NAI Proposal #2

**Description:** Several variations of the "Skyhook" type schemes could be made to increase the possibility of engagement even under poor visibility conditions. Such variations are:

- (a) Fire rocket attached to short line to left of balloon supported cable and fly thereafter to the right. This maneuver would drag the plane's cable across the balloon's cable and give greater possibility of attachment.
- (b) Paravane, drone, or homing device could be flown parallel to the pickup aircraft supporting a line horizontally between them, which would intersect the balloon supported cable.

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APPENDIX II  
(Cont'd)

North American Instruments Idea #7 (Cont'd)

- Description: (Cont'd)** (c) The aircraft could pay out line by trailing a drag chute as it passed the balloon supported cable and then quickly turn, in order to drag the cable across the balloon cable.
- Advantages:**
- (a) All advantages of "Skyhook" type systems
  - (b) Increased capability of restricted vision operation
  - (c) Less hazard to aircraft
- Disadvantages:**
- (a) More complex than fork or boom systems
  - (b) Possibility of attachment by dragging one cable across another is untested
  - (c) Vertical rise of this type of pickup may be somewhat less steep than that of the "Skyhook" and fork technique

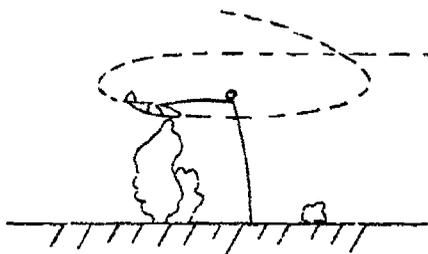
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North American Instruments Idea #8



- Class of Idea:** Extension
- Related Systems:** AAE Proposal #13, Fulton "Skyhook", and NAI Idea #2
- Description:** A horizontal boom might be used to contact the anchored "Skyhook" type systems, pay out enough line to use as radius for turn, and allow the aircraft to then be spiraled upward in such a fashion as to apply very little g load to subject and give very near vertical rise. The schemes previously described in NAI Idea #7 could also be used to engage the anchored cable.
- Advantages:**
- (a) Small g load applied to subject
  - (b) Near vertical rise
  - (c) Possibility of restricted vision use
- Disadvantages:**
- (a) Balloon may not remain stationary as center for circling aircraft and subject may be jerked off ground on first contact unless staked in
  - (b) More complicated than standard "Skyhook" fork type of pickup

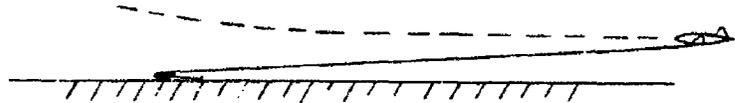
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North American Instruments Idea #9



**Class of Idea:** Extension

**Related Systems:** AAE Proposals #6 and NAI Idea #1

**Description:** A drone with line attached could be used to fly ahead of the pick-up aircraft, land or crash, stake itself to the ground, and allow a few seconds for the subject to get into craft itself or harness attached, before he is snatched off the ground. Increases the time for subject to enter the required equipment which he has available in AAE Proposal #6.

**Advantages:**

- (a) Increased opportunity to make contact
- (b) No equipment required for subject

**Disadvantages:**

- (a) Long line
- (b) Large cleared area required
- (c) Very short duration of opportunity to make contact
- (d) High g loading on subject
- (e) Restricted visibility operation difficult

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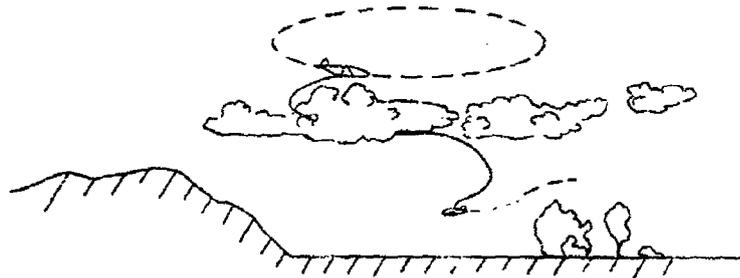
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North American Instruments Idea #10



**Class of Idea:** Extension

**Related Systems:** AAE Proposal #10, Fulton "Rope Trick"

**Description:** A parasite piloted aircraft of minimum complexity could be attached to the mother craft by a rather long line in order to allow maneuverability for search and accurate emplacement of pickup gear. Landing might be accomplished by conventional procedure or by other means such as parachute, etc. Take-off would be of the Fulton or AAE "Long Line" type or by towing off the small aircraft.

**Advantages:**

- (a) Applicable to use where low cloud layer, etc. exists.
- (b) No equipment for subject
- (c) Human guidance system allows judgment, identification, etc.

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APPENDIX II  
(Cont'd)

North American Instruments Idea #10 (Cont'd)

Advantages: (Cont'd)

- (d) Pilot in parasite aircraft can assist subject if injured
- (e) Mother aircraft not subjected to risk of low altitude operation

Disadvantages:

- (a) Complex system
- (b) Landing scheme will require development
- (c) Long line
- (d) Risks another life in addition to that of the subject
- (e) Not suitable for operation in all conditions of poor visibility.

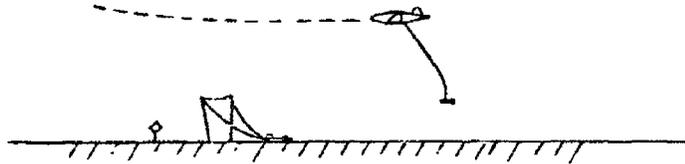
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North American Instruments Idea #11



**Class of Idea:** New

**Related Systems:** AAE Standard pickup system, and NAI Proposal #1

**Description:** A system involving a single aircraft towing a homing device at the end of a relatively long cable would enable the very accurate guidance of cable through the subject's pickup gear and insure engagement. Homing and guidance system, such as radar, infra-red, etc., could be utilized from existing homing missiles.

**Advantages:**

- (a) Poor visibility operation possible
- (b) Hazard to aircraft minimized
- (c) Piloting technique minimized
- (d) Development of homing head probably amounts to adaptation of existing systems

**Disadvantages:**

- (a) Homing device is hazard to subject
- (b) High "g" loading on subject
- (c) Large cleared area involved
- (d) Requires target and some gear for the subject

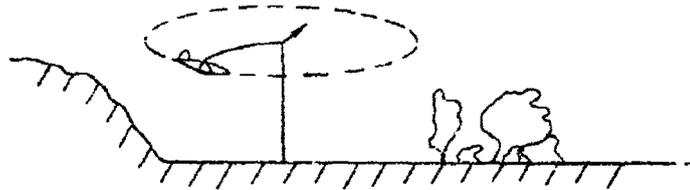
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APPENDIX II  
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North American Instruments Idea #12



**Class of Idea:** Extension

**Related Systems:** AAE Proposal #1, 3, 10, and Fulton "Rope Trick"

**Description:** A drone type device capable of producing thrust could be used to maintain the end of a staked line at the center of a circle which the aircraft describes at relatively low altitude. Pick-up could be accomplished by spiraling upward.

**Advantages:**

- (a) A very short vertical line could be used thus allowing very low altitude operation and minimizing the total line length without the danger of sweeping obstacles on the ground.
- (b) Low "g" loading applied to subject
- (c) Perhaps amenable to restricted visibility operation

**Disadvantages:**

- (a) A device capable of producing and directing the required thrust would require development
- (b) Limited opportunity for engagement since thrust production probably of short duration

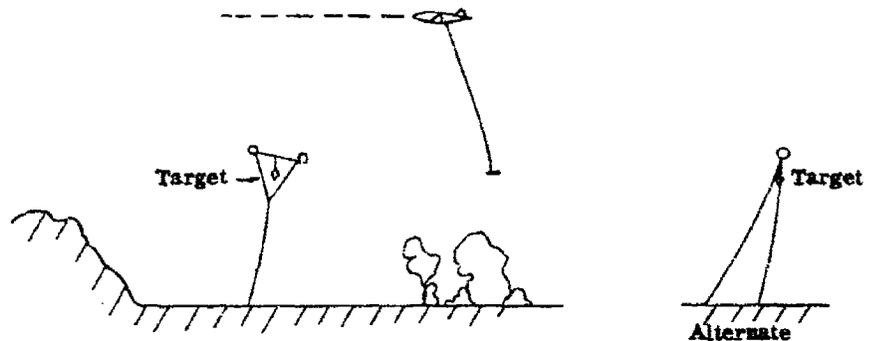
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APPENDIX II  
(Cont'd)

North American Instruments Idea #13



**Class of Idea:** Extension

**Related System:** AAE Standard technique, AAE Proposals #7 and 13, Fulton "Skyhook", NAI Proposals 1 and 2, NAI Ideas #10 and 11.

**Description:** A homing device could be towed on a relatively long line beneath aircraft to intersect a "Skyhook" which involves two balloons with a spreader and target beneath. This system would give a large target area both horizontally and vertically and would be particularly adaptable to conditions of poor visibility and obstructed terrain. Fairly good vertical rise for subject should also result. An alternate "Skyhook" could utilize a V shape cable supported at the center by balloon and anchored at both ends on the ground.

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APPENDIX II  
(Cont'd)

North American Instruments Idea #13 (Cont'd)

Advantages:

- (a) Restricted visibility possibilities are good
- (b) Hazard to aircraft and subject minimized
- (c) Vertical rise possibilities are good

Disadvantages:

- (a) Somewhat complicated system for both subject and aircraft
- (b) Dropping assembled rig is difficult

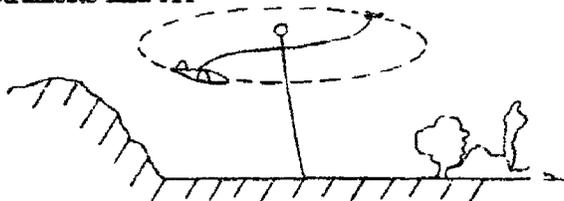
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APPENDIX II  
(Cont'd)

North American Instruments Idea #14



- Class of Idea:** Extension
- Related Systems:** AAE Proposal #1, 7, 13, Fulton "Skyhook", and NAI Idea #6.
- Description:** A plane and drone with rope stretched between could circle at low altitude about a short "Skyhook" type rig to allow greater duration of opportunity to engage and would minimize the cable lengths required for continuous contact. Combining special for pickup.
- Advantages:**
- (a) Difficulty of control of altitude of end of cable described in AAE experiments would be eliminated.
  - (b) Improved opportunity to engage "Skyhook" cable and correct piloting errors.
- Disadvantages:**
- (a) The system is not amenable to poor visibility conditions.
  - (b) Complexity.

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