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EARLY FLIGHT TEST EXPERIENCE WITH COCKPIT DISPLAYED TRAFFIC INFORMATION (CDTI)

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SUMMARY

During recent years, aviation growth rates have been outstripping the ability of the air traffic control system to efficiently accommodate the ever-increasing demand. Studies initiated during the early 1970's by MIT provided initial exploration of traffic situation display concepts in a simulation environment and demonstrated pilot acceptance of traffic information. During the present study, coded symbology, based on the results of early human factors studies, was displayed on the electronic horizontal situation indicator and flight tested on an advanced research aircraft. The primary objective was to subject the coded traffic symbology to a realistic environment and to assess its value by means of a direct comparison with simple, uncoded traffic symbology. The tests consisted of 28 curved, decelerating approaches, flown by research-pilot flight crews. The traffic scenarios involved both conflict-free and blunder situations.

Subjective pilot commentary was obtained through the use of a questionnaire and extensive pilot debriefing sessions. The results of these debriefing sessions group conveniently under either of two categories: display factors or task performance. A major item under the display factor category was the problem of display clutter. The primary contributors to clutter were the use of large map-scale factors, the use of traffic data blocks, and the presentation of more than a few aircraft. In terms of task performance, the CDTI was found to provide excellent overall situation awareness. Additionally, the pilots expressed a willingness to utilize lesser spacing than the 2-1/2 mile separation prescribed during these tests. Aside from consideration of traffic symbology, *per se*, this work, accomplished

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in a flight environment, has provided considerable insight for further defining areas of CDTI research emphasis.

INTRODUCTION

During recent years, aviation growth rates have been outstripping the ability of the air traffic control (ATC) system to efficiently accommodate the ever-increasing demand. Although the literature (ref. 1) has contained proposals for the airborne display of traffic information since the mid-1940's, recent technological advances, which offer a feasible means for providing traffic information in the cockpit, have resulted in a resurgence of interest in exploring potential benefits to safety, efficiency, and capacity offered by such a concept.

Studies initiated during the early 1970's by MIT, under FAA sponsorship, provided initial exploration of traffic situation display concepts in a simulation environment and demonstrated pilot acceptance of traffic information (ref. 2). More recently, a joint FAA/NASA Program has been undertaken to explore potential Cockpit Display of Traffic Information (CDTI) applications through the use of full-system studies, i.e., the real-world environment would be closely approximated. A first step under the joint program was a study (ref. 3) to obtain a set of guidelines for display content, symbology, and format that would be used for subsequent research, the general intent being to provide a basis for standardizing a display for use in follow-on CDTI experiments. That study, involving commercial airline pilots in group sessions during which static displays were viewed on a projection screen and rated, resulted in the definition of a preferred set of coded symbology.

During the present study, coded symbology, based on the results of reference 3, was displayed on the electronic horizontal situation indicator (EHSI) and flight tested on the Terminal Configured Vehicle (TCV) research aircraft. The primary objective was to subject the coded traffic symbology to a realistic flight environment and to assess its value by means of a direct comparison with simple, uncoded traffic symbology. These tests consisted of a total of 28 curved, decelerating approaches, flown by research-pilot flight crews. The traffic scenarios involved both conflict-free and blunder situations. Pilot workload variations were accomplished by use of two levels of control automation available in the research aircraft. Subjective pilot commentary was obtained through the use of a questionnaire and extensive pilot debriefing sessions. Aside from considerations of traffic symbology, per se, this work, accomplished in a flight environment, has provided considerable insight for further defining areas of research emphasis.

RESEARCH SYSTEM

Research Aircraft

The major research system used in this experiment was the NASA TCV Boeing 737 jet transport aircraft (ref. 4). A simplified diagram of this aircraft and the major research systems is shown in figure 1. This aircraft incorporated a fly-by-wire control system in the aft flight deck (AFD) to provide flexibility in implementing advanced control concepts. The AFD, figure 2, was configured for a two-man-crew operation and equipped with functional controls, indicators, and instruments that provide a workload representative of an advanced aircraft flight deck environment. The major research systems include the flight control computer system and the navigation/guidance and electronic display systems.

Control Modes. - In order to vary pilot workload, two levels of control automation were used: velocity control-wheel-steering (VCWS) and attitude control-wheel-steering (ACWS). Both control systems are basically rate command proportional to control input once the control is positioned outside an electrical deadband, the center position of which is defined by a mechanical detent. The primary difference in the systems is the aircraft state that is maintained with the control in the detent. With no control input, the ACWS maintains aircraft pitch attitude and heading. With no control input, the VCWS maintains vertical flightpath angle and ground track angle. Generally, the workload using VCWS is much lower than with ACWS. Block diagrams of the longitudinal and lateral axes are given in figures 3 and 4 for these systems. With both modes, an autothrottle system was utilized, with the crew manually selecting the desired speed via a control panel.

Displays. - The primary flight displays for the AFD were four, monochromatic cathode-ray tubes (CRT), driven by the navigation/guidance and electronic display computers. Two of the CRT's functioned as Electronic-Attitude-Director-Indicators (EADI); and the remaining two, as Electronic-Horizontal-Situation-Indicators (EHSI). They were located on the cockpit panel in the same general area as their mechanical counterparts (figure 5). A description of the EADI is presented in reference 5. The ESHI, which measured 5" by 7", was basically a moving map display on which traffic information was superimposed to provide the CDTI for this study.

Traffic Generation

The displayed traffic was generated from an on-board data tape which had been previously recorded using Langley's real-time simulation facility. Specifically, this non-interactive traffic was created by using a piloted simulation capability, wherein an aircraft made approaches along several defined routes that corresponded to the airway structure prescribed by the test scenarios. These individual approaches were recorded and were then merged into a set of data that was both position and time correlated. Finally, the resulting data was geographically correlated and adjusted to match the runway and terrain configuration of the NASA Wallops area where the flight tests were conducted. The effective output of this merged data was the representation of numerous aircraft, following several flightpaths, and landing with a nominal separation of 2-1/2 miles at the runway threshold.

CDTI DISPLAY FORMAT

General Format

The general format for the CDTI was a "course-up" display with a fixed own-ship symbol centered laterally and positioned longitudinally such that two-thirds of the viewing area was ahead of own-ship. A magnetic course tape was shown along the upper portion of the display, and various digital information was shown in the lower corners (figure 6).

A sufficiently high update rate was used so that motion of the CDTI map appeared to be continuous with respect to own-ship. Geographical position updating of the traffic, on the other hand, was done at 4-second intervals in order to simulate the current terminal area radar sweep rate.

The test subjects had direct control over several aspects of the CDTI. Of primary importance were the capability for selecting traffic data blocks and map scale factors. The six map scales, ranging from 1 to 32 miles per inch, were selectable using a rotary knob. (Due to limited computer capacity, independent selection of map scale for the two CDTI's was not possible.) The traffic data block option was selectable using a push button. Selection of this option caused the data block for each displayed traffic symbol to appear. The capability to individually select data blocks for specific traffic, as suggested in reference 3, was not available.

Traffic Symbology

In addition to the set of coded traffic symbology, an uncoded traffic symbol was used to obtain a comparative evaluation (figure 7). The basic characteristic of the uncoded traffic symbol is that ground track is explicitly shown. The coded symbology, based on the results of reference 3, explicitly identified relative altitude and indicated whether the traffic was under ATC control and whether it was CDTI equipped. With regard to altitude encoding, the altitude band of ±1000 feet was used to define "own-ship altitude."

Additionally, as shown in figure 8, the traffic symbology included position prediction, position history, and data blocks. In all cases, the position history depicted aircraft position for the three previous updates. For the coded symbology case, the position predictor was simply a velocity vector scaled to represent either a 30- or 90-second prediction; the longer prediction being used in conjunction with the 2 n.m./in., and larger, scale factors. For the uncoded symbology case, and for own-ship in all cases, the prediction vectors included bank angle information. The data blocks contained alpha-numeric information concerning aircraft identification, altitude, and ground-speed for each aircraft.

Terminal Area Route Structure

The overall route structure is shown in figure 9. The route utilized by own-ship, and indicated by the solid line, was based on an experimental Standard Terminal Arrival Route (STAR) developed for the TCV Program. This route, designed to exploit the expanded coverage provided by MLS, included designated waypoints, with the nominal altitudes and speeds dictated by the STAR as shown in figure 10. In addition, three alternate arrival routes, indicated by the dashed lines, were provided to represent a typical terminal area.

TRAFFIC SCENARIO

Four sets of data, or scenarios, were generated. In all of the scenarios, own-ship was positioned to be fifth in the landing sequence, which involved seven landing aircraft. One additional aircraft was programmed to overfly the terminal area at a high altitude.

Figure 11 illustrates the general traffic arrangement, where the numerals designate the landing sequence for aircraft numbered 1 through number 7; aircraft number 8 is a constant velocity, constant altitude overflight of the simulated terminal area. The intended flightpath of number 8, unlike the STAR and the alternate routes, was not displayed. In an effort to add realism, aircraft number 4 did not follow the proposed path exactly, but delayed its first turn, and then paralleled the desired path until it intercepted the straight-in portion.

Non-Conflict Scenarios

Two conflict-free scenarios were generated for this study, their differences being the initial position and flightpath of aircraft number 6. For the first scenario, aircraft number 6 was positioned on one of the alternate routes (figure 11) and was programmed to merge 2-1/2 miles behind own-ship in the landing sequence. For the second scenario, aircraft number 6 was positioned on another of the alternate paths behind aircraft number 4 (figure 12) and was programmed to follow the same flightpath as aircraft number 4, again merging 2-1/2 miles behind own-ship.

Conflict Scenarios

A conflict scenario was generated from each of the two conflict-free scenarios so that aircraft number 6 would violate own-ship's airspace. The conflict situation relating to the first scenario was produced by adjusting aircraft number 6's initial position along its route, and then changing its flightpath to delete the last turn. This path and the point of conflict are shown in figure 13. The other conflict situation was created by adjusting the initial conditions of aircraft number 6 in the second scenario, and modifying its flightpath to a straight line (figure 14). In both conflict scenarios, the vertical path of the conflicting aircraft was adjusted to coincide with the altitude profile of own-ship at the point of conflict.

RESULTS AND DISCUSSION

The operational task was to execute an approach while monitoring the traffic situation and reacting to imminent conflicts. Because of the limited flight time available for these tests, the pilot questionnaire was designed to stimulate formulation of an overall assessment based on the entire flight series, rather than attempting to concentrate on sorting-out minute, individual effects for each parameter. At the conclusion of the test series, each pilot independently filled-in his questionnaire, followed by a debriefing that was attended by both crew members. Following individual debriefings of the two crews, two additional debriefing sessions were held involving three of the pilots in mutual discussions. (The fourth pilot, who was a contractor-furnished pilot, was not available for the debriefing, but the other crew member spoke for him.) The results of the debriefing sessions group conveniently under either of two categories: display factors or task performance.

DISPLAY FACTORS

Display Clutter. - Even with the relatively large viewing area offered by the EHSI, both crews indicated that display clutter was a major problem throughout much of the evaluation. As might be expected, conditions that maximized the clutter problem included use of the larger map-scales, selection of aircraft data blocks, and presentation of more than a few aircraft.

Pilot commentary indicated that the presentation of traffic generally resulted in his selection of a larger map-scale factor than he would have ordinarily used for the navigation task. For the navigation task, he preferred the smaller scale in order to achieve a desired level of tracking performance along the curved approach paths flown during these tests. For the traffic-monitoring task, on the other hand, he preferred a larger scale that would maximize the lead-time available for detection of potentially conflicting traffic. From a clutter standpoint, then, the larger scale factors preferred for traffic monitoring, tended to cluster the displayed information into a smaller area of the displays, thus increasing the difficulty of information extraction.

The other major source of clutter, also related to the number of aircraft displayed, but a contributor in its own right, was the aircraft data blocks, which could not be selected individually during these tests. Even with coded symbology, it was necessary, from time-to-time, to display the data blocks in order to obtain detailed vertical situation information (i.e., altitude and altitude rate).

The most direct contributor to display clutter was the number of aircraft displayed. Recognizing this relationship, and despite the fact that the number of aircraft displayed at any given time never exceeded six, the test subjects repeatedly emphasized displeasure regarding the presentation of traffic which they considered to be of no concern. Unfortunately, as was amply evident from the debriefing, defining which aircraft might be of concern to the pilot is a complex problem requiring thorough investigation.

Coded Symbology. - As previously described, the coded symbology graphically identified the traffic with respect to relative altitude, whether CDTI equipped, and whether under ATC control. The initial impression, obtained from preliminary comments of the first flight crew was that the coded symbology was beneficial from a total awareness standpoint, particularly during high workload conditions. Upon conclusion of this study, however, the test subjects unanimously concluded that they were almost totally disinterested in knowing whether the other traffic was under ATC control or whether they were CDTI equipped. In essence, they were saying that in a non-conflict situation it is unimportant information, and in a conflict situation they are in a "defensive posture."

Having indicated a lack of interest in some of the encoded information, the pilots were asked to define an information hierarchy in order to provide additional insight as to how the information was used for traffic-monitoring purposes. This hierarchy shown in table 1, lists the information elements in descending order of importance and provides a quantitative ranking on a scale of zero to ten. The principal benefit of the coded symbology, as identified by the test subjects was that the altitude encoding provided a convenient means for formulating a three dimensional assessment of the situation thus avoiding the necessity for continuously displaying the data blocks; however, the data blocks were always required and used in assessing/resolving potential conflicts.

TABLE 1

Information Hierarchy

Horizontal Position	10
Horizontal Position Prediction	10
Altitude	10
Altitude Rate	8
ATC Control	2
CDTI Equippage	1

The symbol size used during this study corresponded to a subtended viewing angle of 0.4°. Although this symbol size was considered to be satisfactory for the uncoded symbology, it was only marginally satisfactory for the coded symbology. One factor that may have contributed to this result was the halving of the symbol size to designate relative altitude.

TASK PERFORMANCE

Situational Awareness. - Presentation of traffic information on the EHSI, which was part of the pilots' primary scan pattern, resulted in a high level of overall situational awareness, even for the aircraft control mode corresponding to the highest level of pilot effort (i.e., the attitude-CWS). In detecting the programmed conflicts, the pilots utilizing either the coded or uncoded traffic symbology consistently recognized the need for positive action in sufficient time to permit discussion and resolution of the problem through gentle maneuvering. In general, impending conflicts were identified primarily by observing impingement of the threat-aircraft velocity vector on what they considered to be own-ship airspace.

In using the CDTI, the pilots periodically selected the largest scale factor to obtain a strategic view of the traffic situation, but generally utilized the 4 n.mi./in. scale until the final approach phase, when they selected, first, the 2 n.mi./in., and finally, the 1 n.mi./in. scale. Upon recognition of a potential conflict (i.e., any encroachment in the horizontal plane) they would immediately select the data-blocks ON in order to permit a quantitative assessment of the vertical situation. By this process, they were able to quickly dismiss from further consideration those targets which had adequate altitude separation, and having recognized that the threat was false, would have liked to be able to eliminate such aircraft symbols from the display. When the potential conflict, on the other hand, was real, the pilots would determine a method for resolution through discussion of the situation, and then proceed with its execution. The pilots indicated that, if an air traffic controller position had been involved in these tests, they would have had ample time to contact him in the conflict resolution process.

The maneuver preferred by the pilots for resolving the conflicts that occurred during these tests involved maneuvering in the vertical plane. Although the presence, in a high density terminal area, of other aircraft in the same horizontal plane might dictate the use of vertical maneuvering, the preference for vertical maneuvering resulted from having the precise altitude-situation information provided by the data blocks. This preference contrasts sharply with the manner in which they would prefer to maneuver under visual flight conditions. Specifically, under visual conditions, but when the horizon is obscured, they prefer to maneuver in the horizontal plane because of an inherent inability to identify whether the conflicting aircraft is initially above or below own-ship altitude. The conflicts during these tests occurred while own-ship was following a descending flightpath; and the pilots easily resolved the conflicts by simply arresting their descent rate, thereby obtaining vertical separations in excess of 500 feet.

Workload Impact. - It should be emphasized that the advanced control modes and integrated display concepts provided in the research aircraft, coupled with the fact that the test subjects were not responsible for ATC communication, would result in a substantially lower pilot workload than would be encountered in a conventional aircraft performing a standard, terminal-area approach task. However, during these tests, the use of decelerating approaches along a curved flightpath, to represent an advanced operating environment, tended to elevate the pilot workload to a realistic level.

In their effort to optimize the workload distribution, the first flight crew used the first officer as the primary monitor of the traffic situation, in addition to being responsible for operation of the flaps, landing gear, and autothrottle system in response to captain commands, and he provided altitude and speed "call outs." The captain, in addition to the basic task of navigating and controlling the aircraft, monitored the traffic situation. Both pilots monitored the basic aircraft subsystems. The second flight crew distributed their tasks differently, in that, the captain not only performed the functions as the other captain, but also operated autothrottle system and performed as the primary monitor of the traffic situation. The first officer of this crew monitored the subsystems, made altitude and speed "call outs," and provided a backup for traffic monitoring.

All of the pilots agreed that the additional task of monitoring traffic did not adversely affect their traditional piloting task. In fact, in extrapolation of his real-world experiences, the captain of the first crew stated that the traffic display would "provide the ability to 'see' all those called aircraft that have escaped my eyes previously." In essence, it is believed that this implied a reduction in the pilot's cognitive workload. Another point of agreement among the pilots was the compelling nature of the CDTI, leading to an expressed concern that it "may glue eyes inside the cockpit" and may, therefore, be a "possible problem area when untracked traffic exits." Despite the compelling nature of the display, however, the pilots felt that they treated monitoring traffic as a secondary task, with traffic observation falling naturally into their normal scan pattern.

Traffic Separation. - Reduction in longitudinal separation has long been recognized as a vital element in making significant progress toward increased airport capacity. Current standards, primarily based on wake vortex considerations, specify minimum longitudinal separations as a function of the weight categories of the lead and trail aircraft. Assuming that the wake vortex problem could be alleviated, and considerable effort is currently being directed toward that goal, the question arises as to how the minimum standard might be affected by CDTI. One of the goals of the Joint NASA/FAA CDTI Program is to determine the minimum separation that a pilot would be willing to accept, given a traffic display. The nominal separation prescribed for these tests was 2-1/2 n.mi. Although this provided less separation than the current 3 n.mi. minimum standard, the test subjects readily accepted this spacing and even indicated a willingness to consider further reductions in separation.

CONCLUSIONS

During a flight investigation, variations were made in the traffic symbology to assess the impact of coded symbology on pilot situational awareness. On the basis of these tests, the following conclusions are drawn.

1. For both the coded and uncoded symbology cases, ample lead time for detecting and resolving conflicts was provided by the display.

2. Although the pilots agreed that encoding the symbology improved their overall knowledge about the traffic, some of the encoded information (CDTI equippage and ATC control encoding) was of little interest.

3. The most beneficial element in the encoded symbology was altitude; it provided a convenient means for the pilot to formulate a three-dimensional assessment of the situation without continuously displaying aircraft data blocks.

4. The additional task of monitoring traffic did not adversely affect the traditional pilot task, with traffic observation falling naturally into the pilot's normal scan pattern.

5. The 2-1/2 mile, nominal traffic separation prescribed for this investigation does not appear to represent the lower limit from the standpoint of pilot acceptance.

6. Even though a reasonably large display was utilized in these tests, display clutter was the primary problem from the standpoint of information assimilation.

REFERENCES

1. Ewing, D. H.; and Smith, R. W. K.: Teleran-Air Navigation and Traffic Control by Means of Television and Radar. RCA Review, Vol. VII, No. 4, pp. 601-621, December 1946.

2. Connelly, Mark E.: Simulation Studies of Airborne Traffic Situation Display Applications - Final Report. Report ESL-R-751, May 1977.

3. Hart, Sandra G.; and Wempe, Thomas E.: Cockpit Displays of Traffic Information: Airline Pilots' Opinions About Content, Symbology, and Format. NASA TM 78601, August 1979.

4. Staff of Terminal Configured Vehicle Program Office: Terminal Configured Vehicle Program Test Facilities and Experimenter's Guide. NASA Langley Research Center Brochure, October 1977.

5. Steinmetz, George G.; Morello, Samuel A.; Knox, Charles E.; and Person, Lee H., Jr.: A Piloted-Simulation of Two Electronic Display Formats for Approach and Landing. NASA TN D-8183, April 1976.

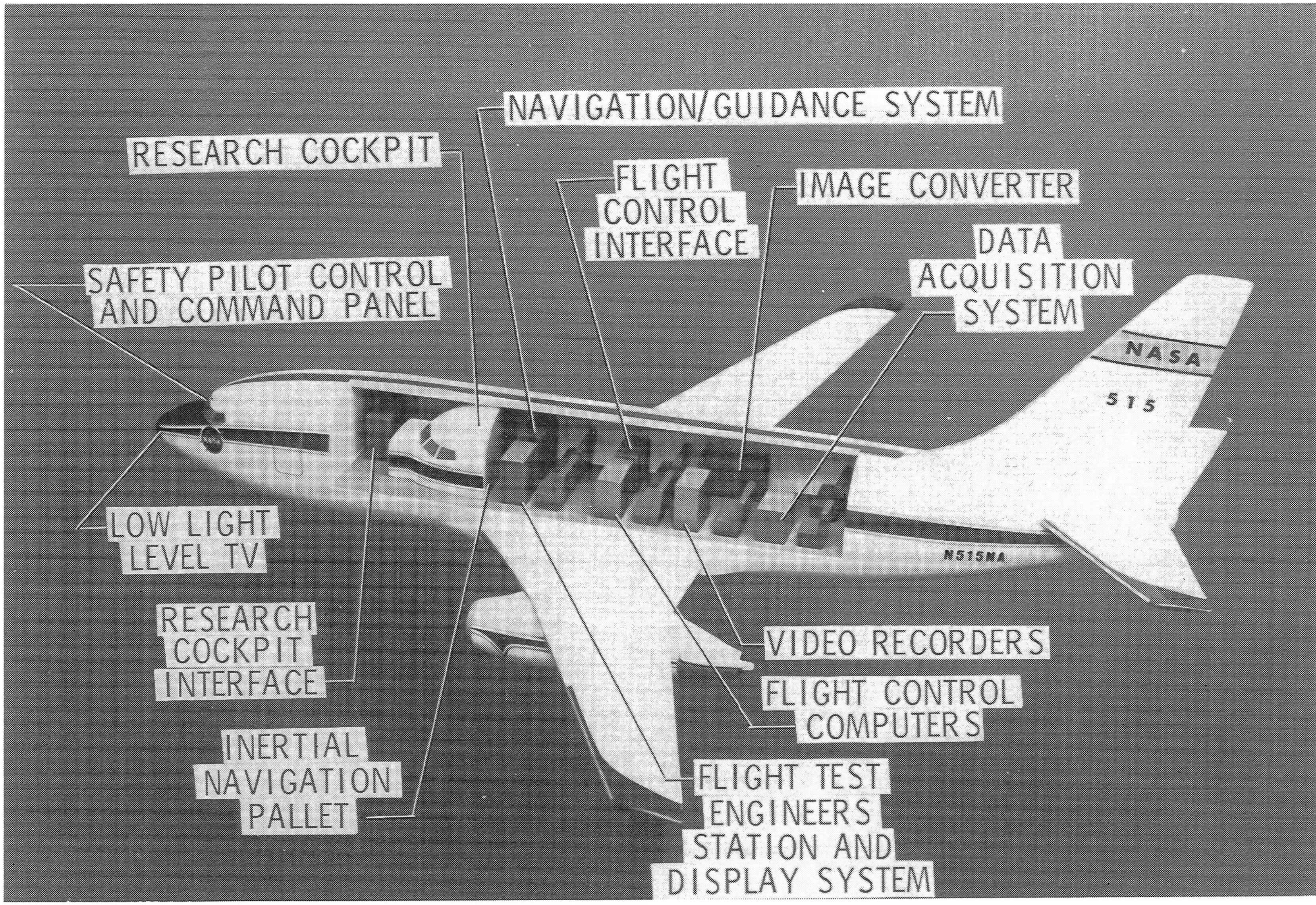

Figure 1. - Research aircraft.

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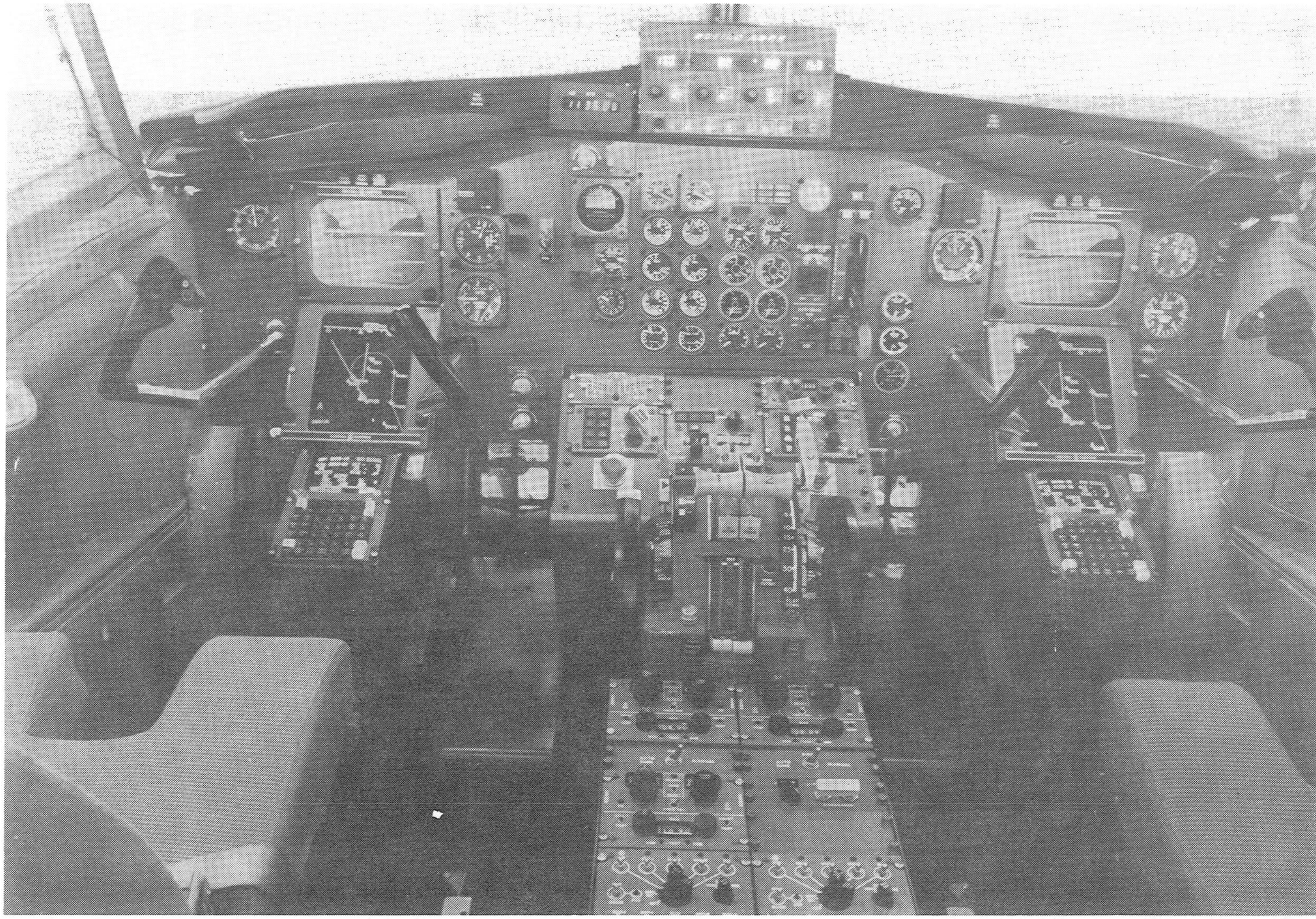

Figure 2. - Aft flight deck.

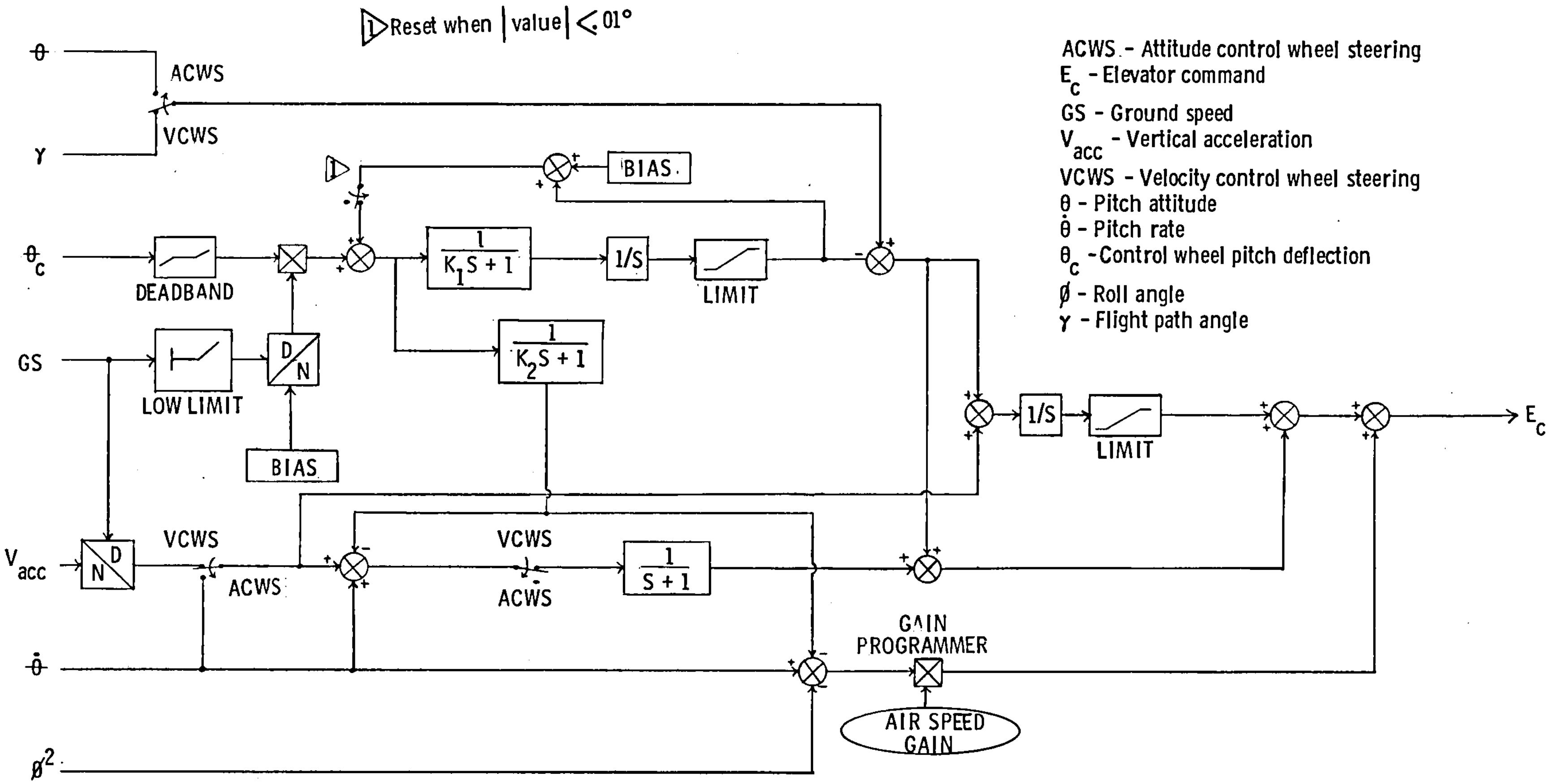

Figure 3. - Longitudinal control axis.

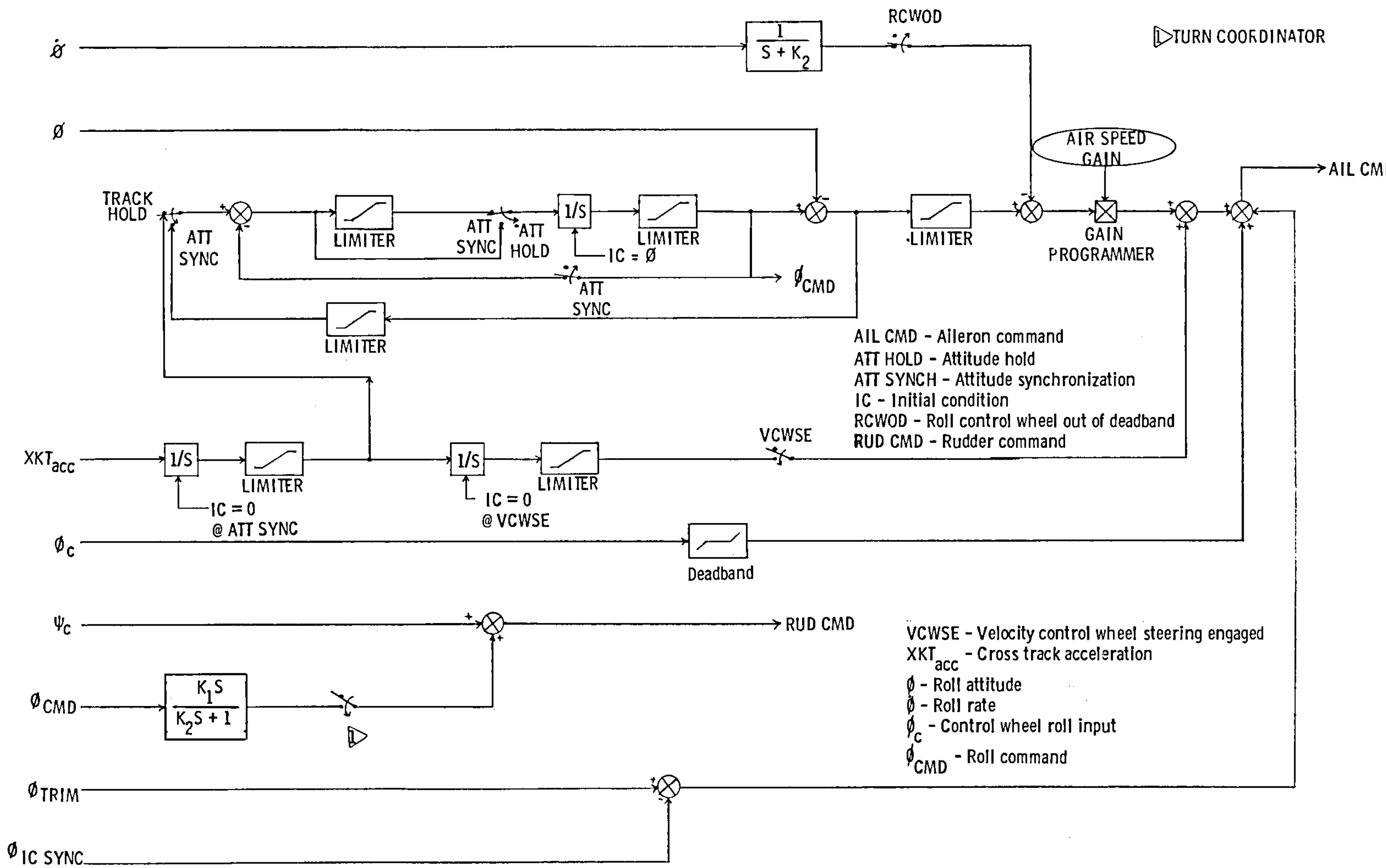

Figure 4. - Lateral control axis.

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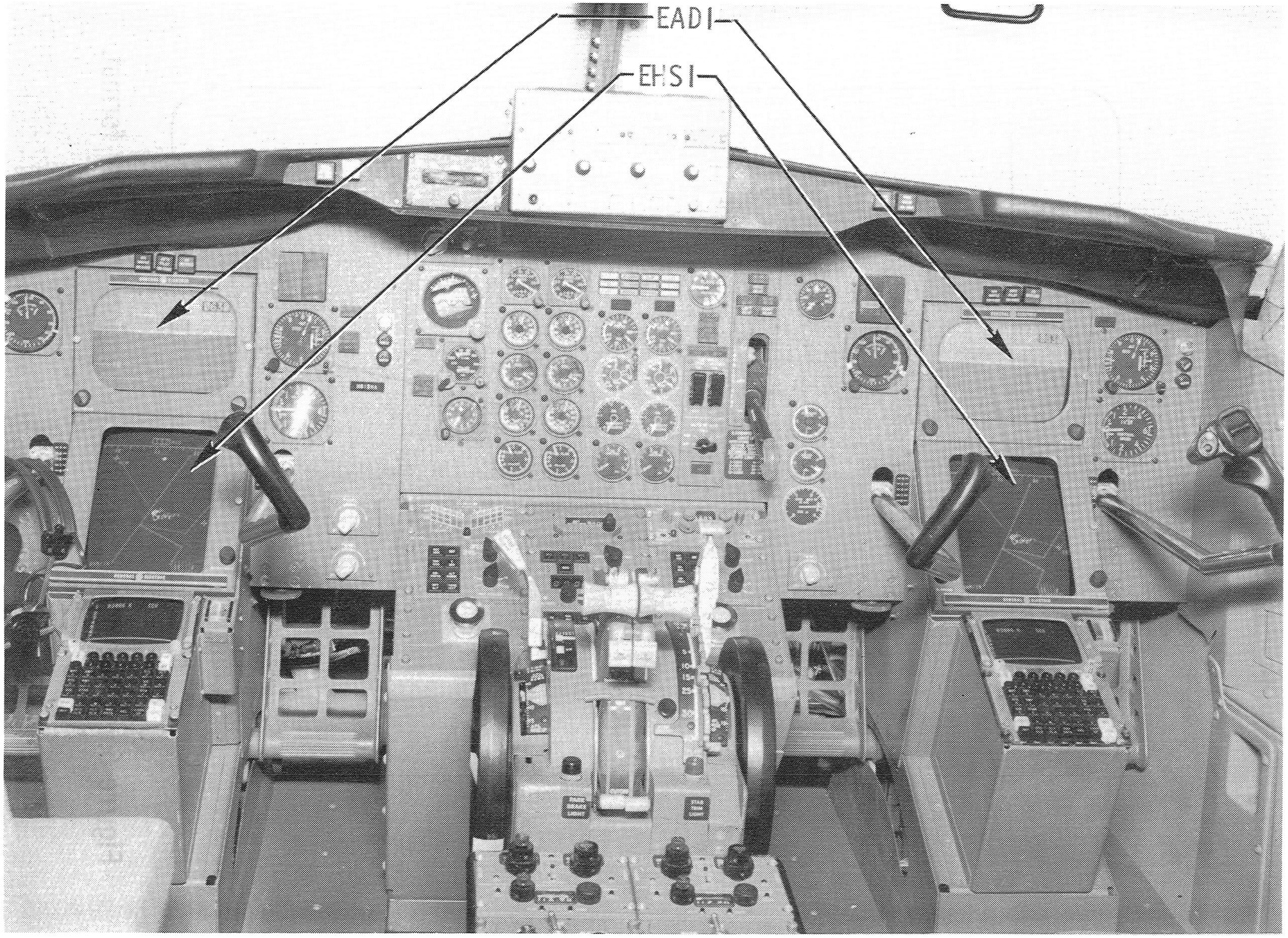

Figure 5. - Cockpit instrument panel.

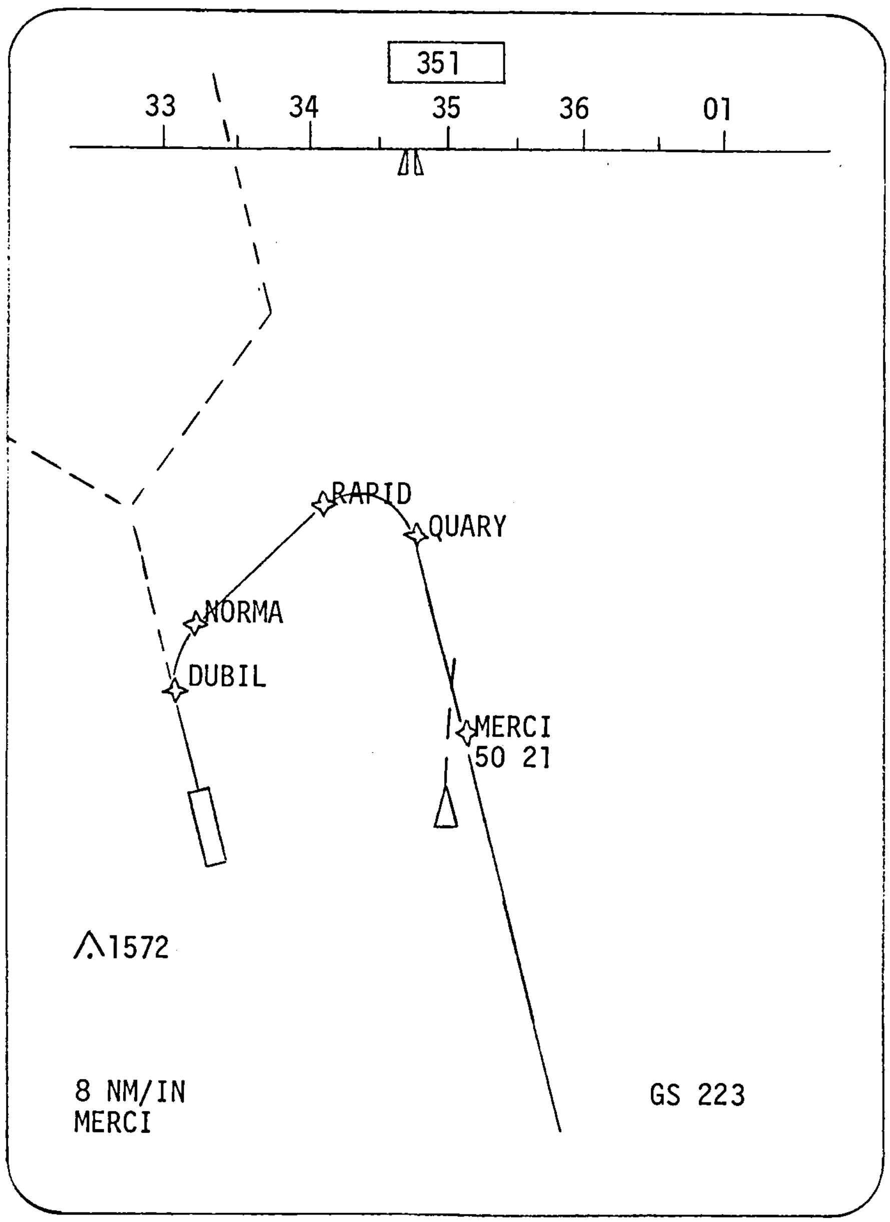

Figure 6. - Electronic Horizontal Situation Indicator format.

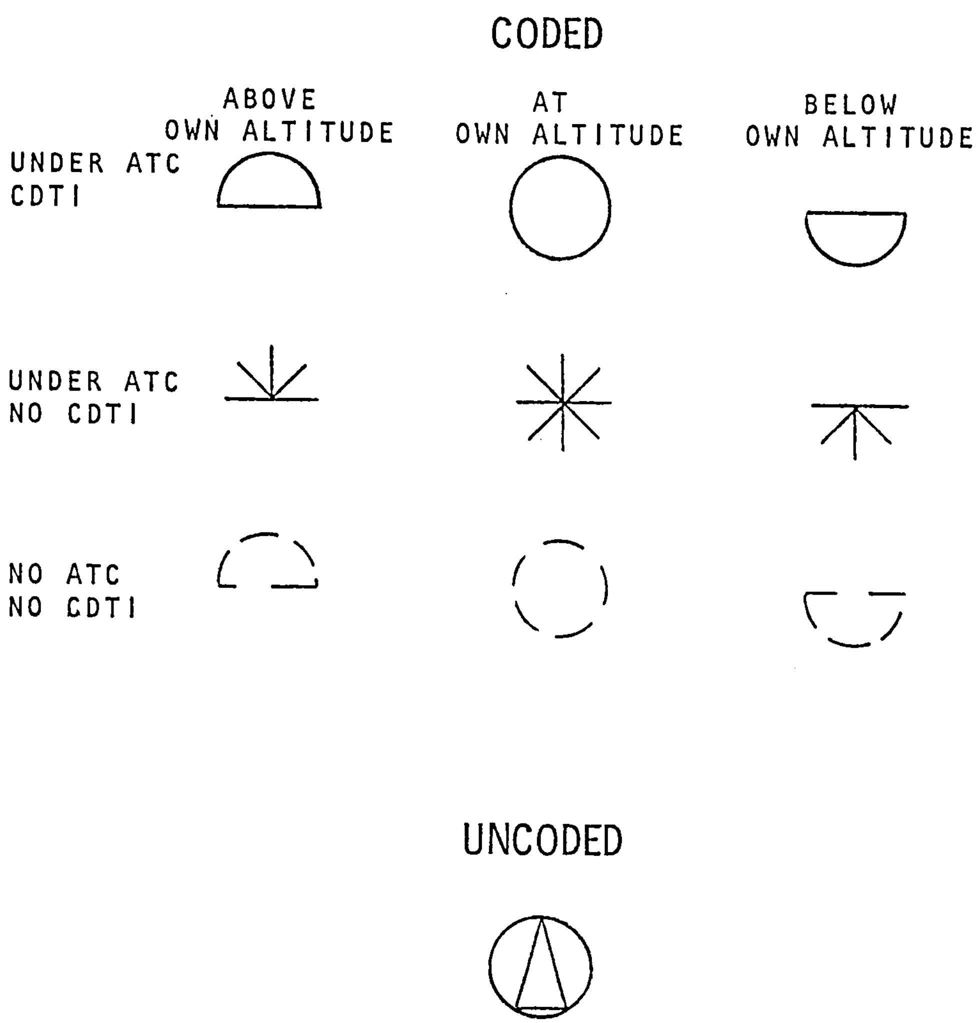

Figure 7. - Traffic symbology.

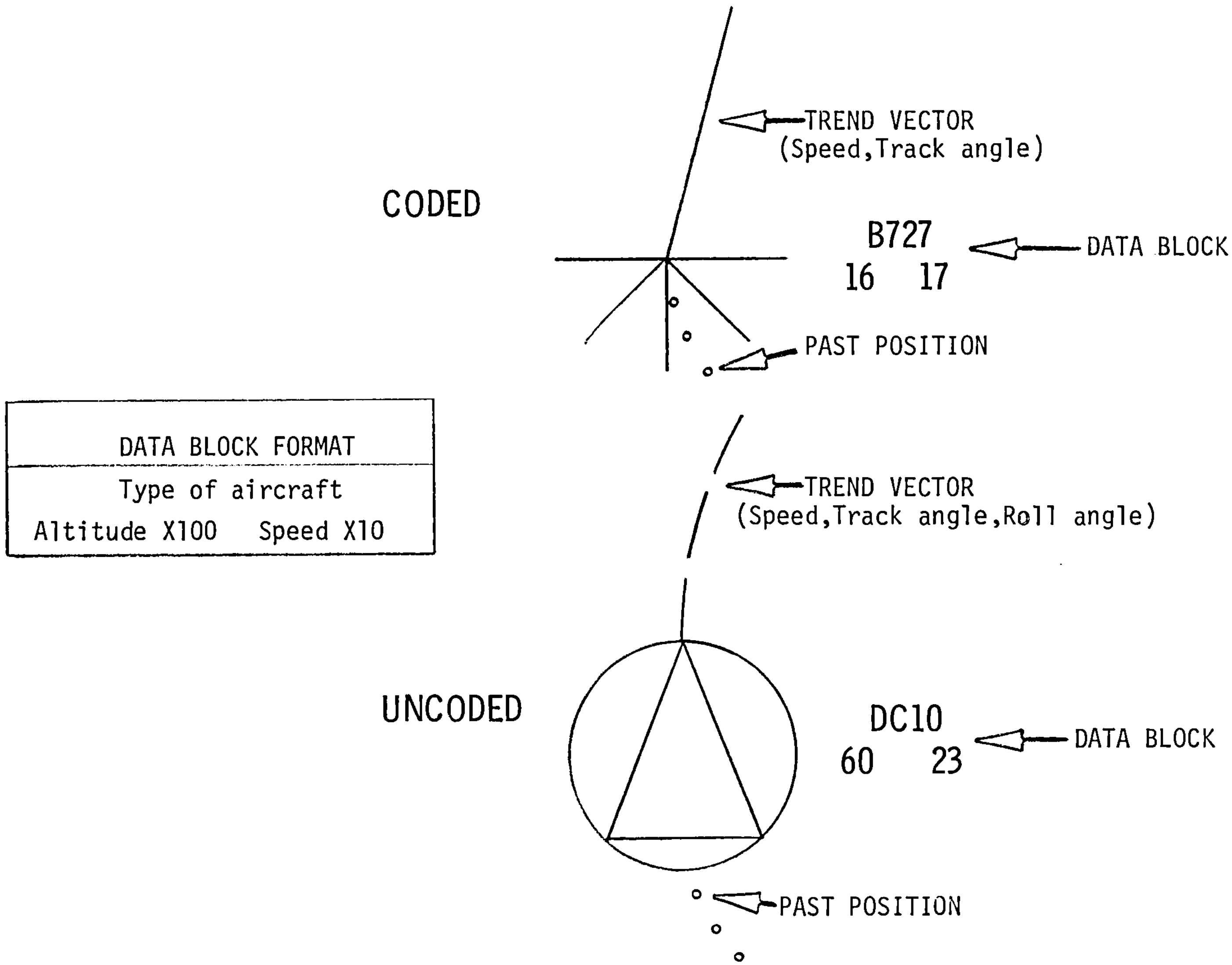

Figure 8. - Traffic symbology with situational information.

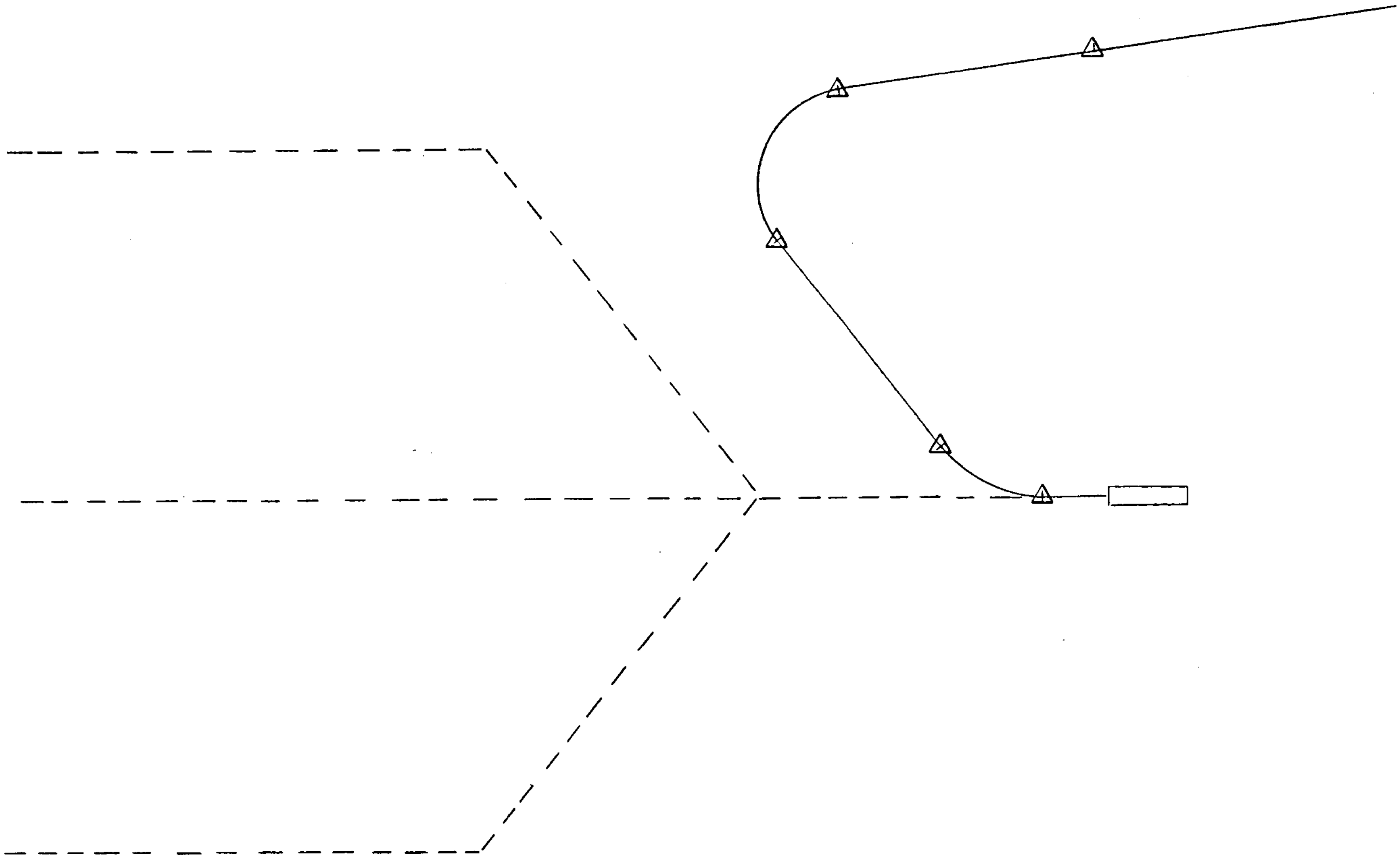

Figure 9. - Route structure.

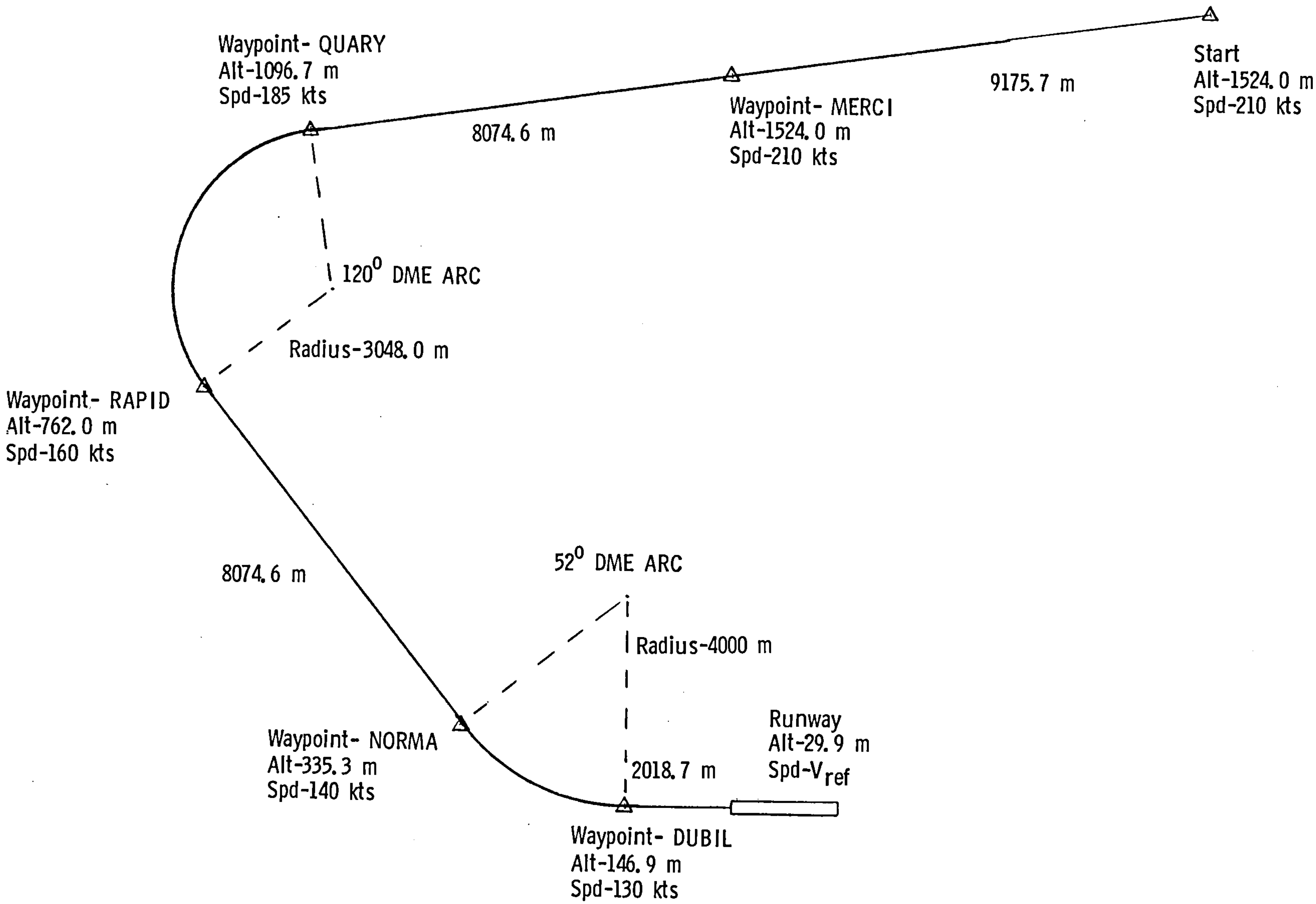

Figure 10. - STAR.

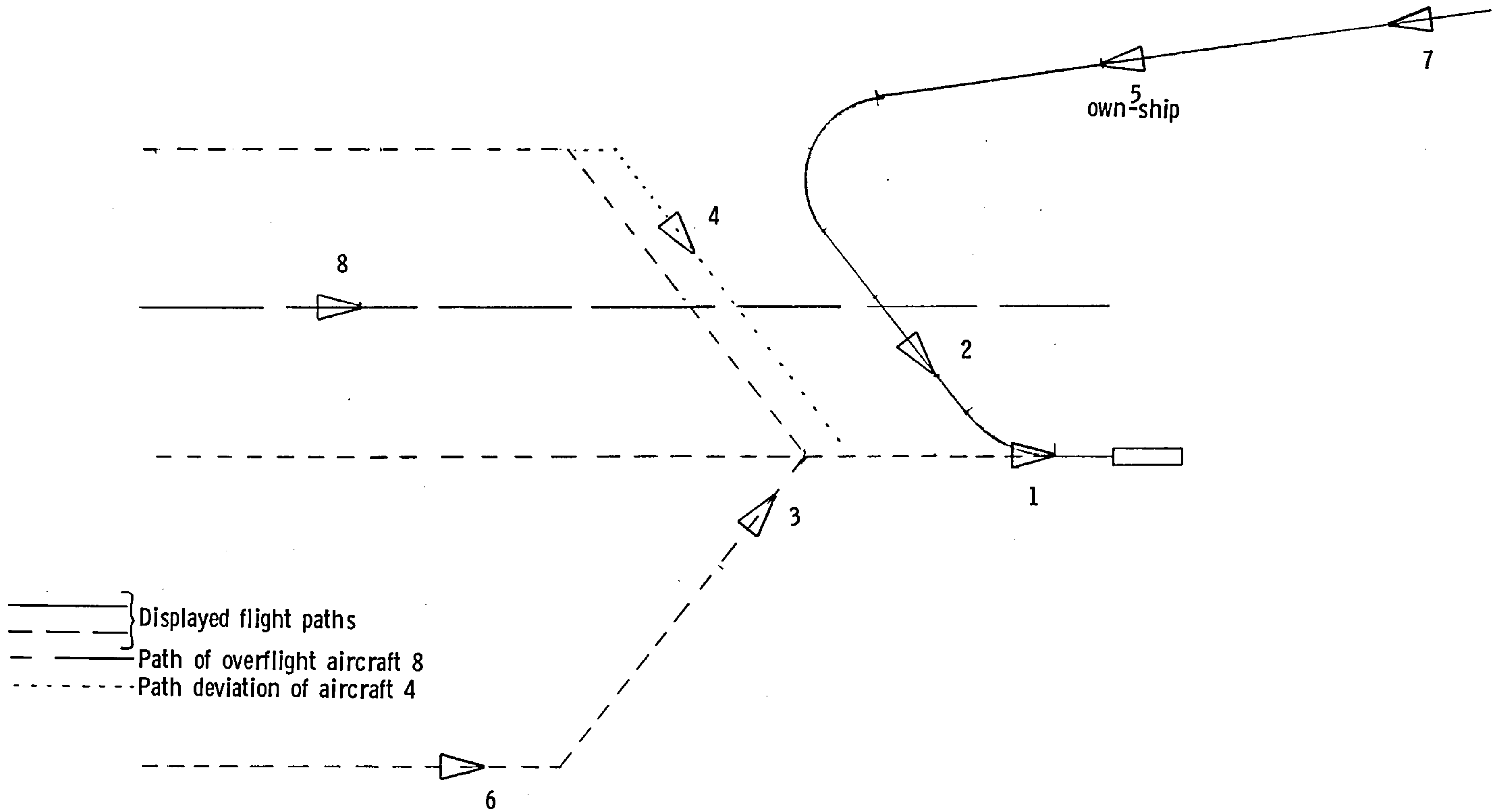

Figure 11. - Traffic scenario 1.

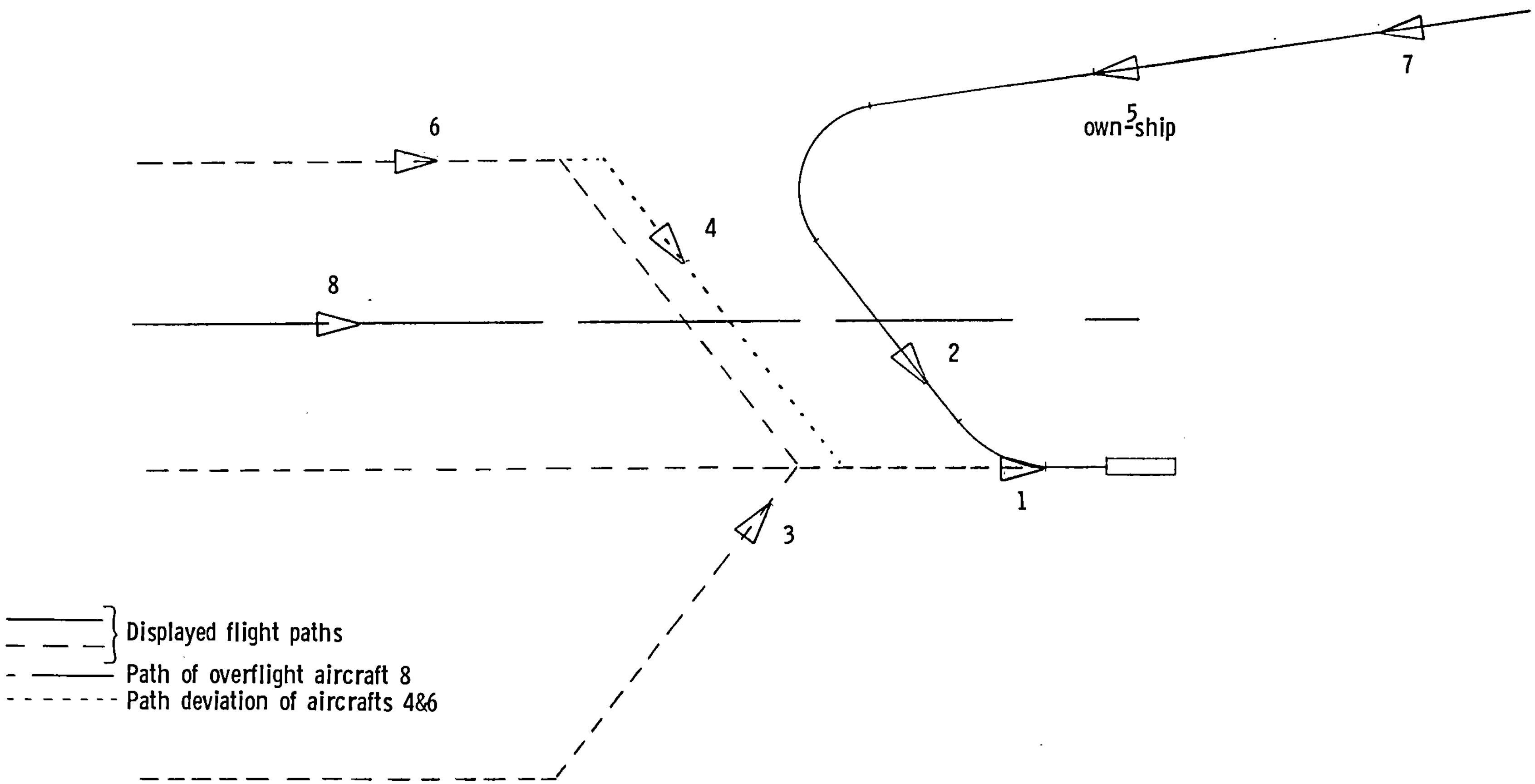

Figure 12. - Traffic scenario 2.

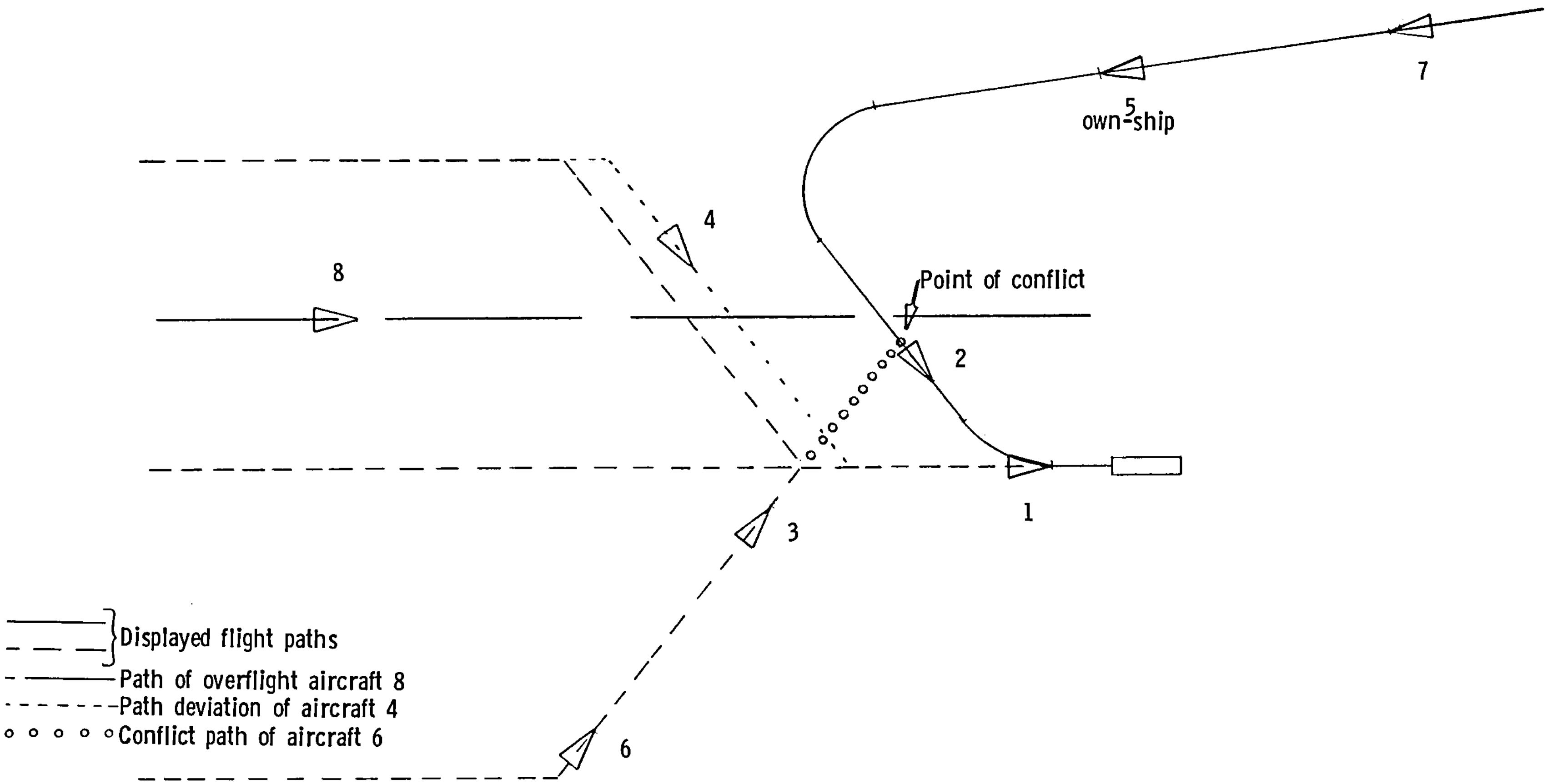

Figure 13. - Traffic scenario 3.

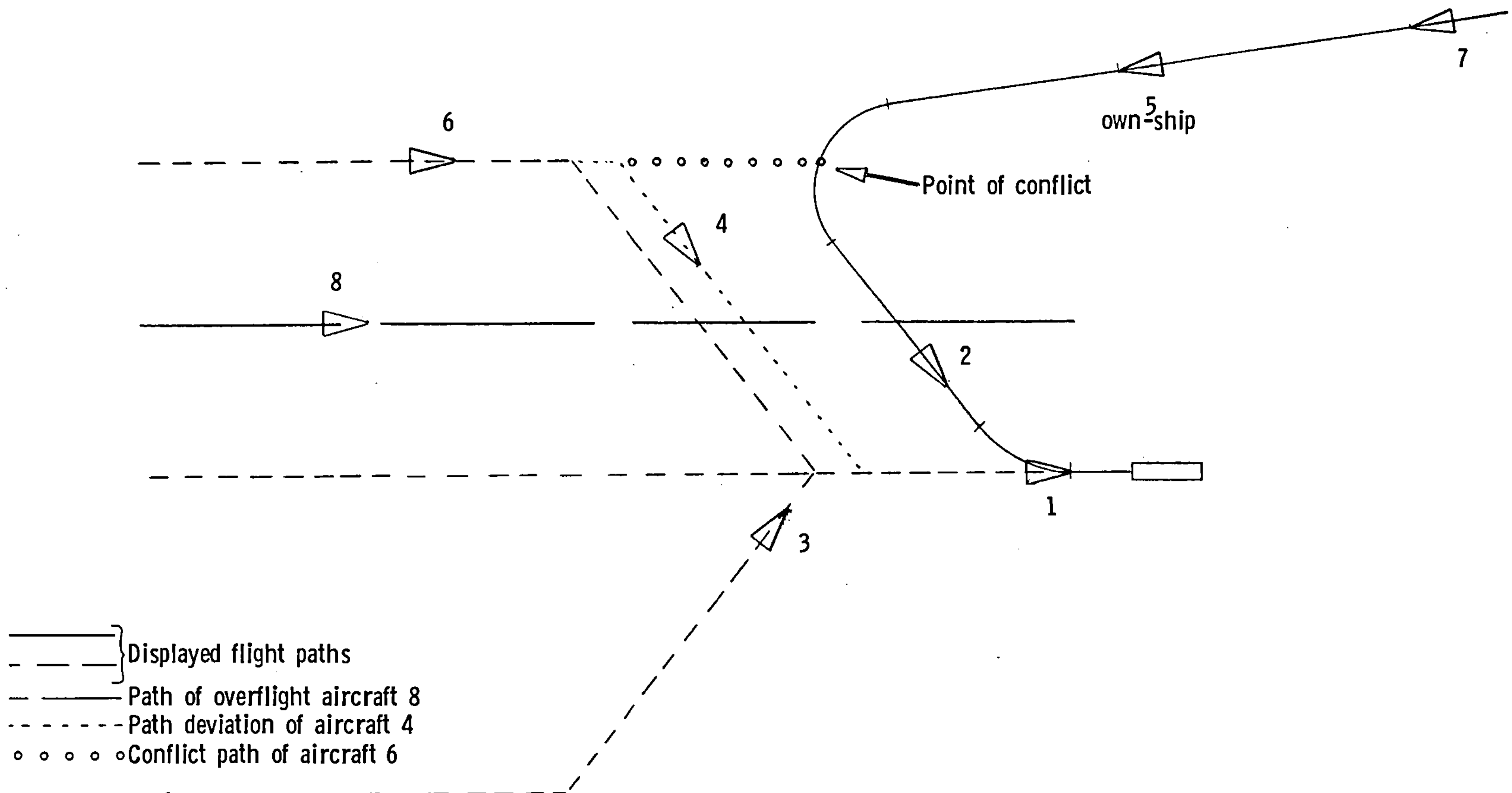

Figure 14. - Traffic scenario 4.

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16. Abstract
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