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# DEVELOPMENT OF AN INTERACTIVE REAL-TIME GRAPHICS SYSTEM FOR THE DISPLAY OF VEHICLE SPACE POSITIONING

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## Abstract

This paper will outline a new approach taken by the NASA Western Aeronautical Test Range to display real-time space positioning data using computer-generated images that produce a graphic representation of an area map integrated with the research flight test aircraft track. This display system supports research flight test requirements of research projects such as the advanced fighter technology integration (AFTI) F-16, F-18 high alpha research vehicle (HARV), AFTI F-111 mission adaptive wing (MAW), F-15, and X-29A forward-swept wing. This paper will discuss the requirements, system configuration and capability, and future system applications.

## Nomenclature

| | |
|---|---|
| ARC | Ames Research Center |
| ATF | Aeronautical Tracking Facility |
| DFRF | Dryden Flight Research Facility |
| DMA | Defense Mapping Agency |
| ETA | estimated time of arrival |
| GPS | global positioning system |
| HARV | high alpha research vehicle |
| MAW | mission adaptive wing |
| MCC | mission control center |
| NASA | National Aeronautics and Space Administration |
| NASP | national aerospace plane |
| RIM | Real-time interactive map |
| TACAN | tactical air navigation |
| TCP/IP | Transmission Control Protocol/Internet Protocol |
| TRAPS | telemetry/radar acquisition and processing system |
| USGS | United States Geological Survey |
| WATR | Western Aeronautical Test Range |

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## Introduction

The Western Aeronautical Test Range (WATR) facilities located at NASA Ames Research Center, Dryden Flight Research Facility (DFRF) at Edwards Air Force Base, California (Fig. 1) are responsible for tracking, data acquisition, real-time processing, and the display of real-time data for missions flown in the Edwards AFB locality.

The primary goal of the WATR facilities at DFRF is to support the agency aeronautics research flight test activity, dealing with high-risk, high-performance vehicles. During research flight test missions, flight data from specially instrumented research flight test vehicles are received by WATR facilities through downlink telemetry data merged with space position data received from one of two Aeronautical Tracking Facilities (ATF). The ATF is equipped with C-band precision tracking radars. These data are then processed and made ready for use by workstations in one of two mission control centers (MCC) (Fig. 2).

The WATR is required to provide accurate information based on data delivered from the ATF to the research analysts, who rely on a variety of displays. One of these displays provides the researcher/analyst and mission controller the ability to monitor the research flight test vehicle track in real-time. The display is required to direct the aircraft toward test areas, as well as away from unauthorized/restricted areas, and monitor the entire flight profile. The mission controller must often provide real-time flight corrections to the pilot for vectoring to predefined test points along the flight path. The MCC personnel must know the exact location of the research flight test vehicle at all times during the mission, and in particular, during emergency situations.

As technology continues to increase the complexity of research aircraft, the requirements placed on the WATR also evolve. More sophisticated space positioning displays are needed with ever-increasing capability and complexity. This paper will discuss the requirement for space position displays, the approach taken at the WATR to satisfy this requirement in the form of system configuration and capability, and the future system applications.

## Requirements

The ATF acquires space positioning data that are transmitted to the real-time processing and display systems. The development of advanced displays is costly in terms of capital investment in equipment and manpower for both hardware and software. The challenge is to develop a display that will generically satisfy the requirements of all research flight test programs. The ability to meet this challenge will reduce the need for specific displays for individual research flight test programs.

The requirements for development of advanced space position displays were initiated by the limitations of the previous display system, in addition to aeronautics program requirements. Previously, radar data were sent to a vertical X-Y plotter, which then plotted the track of the aircraft on paper maps (Fig. 3). The research flight test vehicle space position was determined using two pens, one to display the X-Y axis as if you were at a point in space looking down at the vehicle and the second to display the Z-axis vehicle altitude related to the X-Y point.

For the duration of the test, the aircraft was confined to the boundaries of the particular map being used. Map scale was determined prior to the mission, based on the mission objectives and characteristics. Once the particular map was selected and the plotboard set up for that map, users were restricted to that map for the duration of the mission.

The accuracy of this display was directly proportional to the scale of the map used. If a large scale map were selected, accuracy and detail at specific test points were not available in real-time but had to be generated in the postflight environment.

To eliminate these restrictions, a display was generated that provided flexibility to scale in real-time and detail, based on specific research flight test mission objectives.

During research flight test missions, many items had to be drawn on the map by hand. Altitude restrictions, computing intercept headings, estimated time of arrival (ETA), and projected flightpaths were all manually calculated using compasses, rulers, and preflight considerations. A plotboard operator would monitor the vehicle groundtrack and provide information to the mission controller if the aircraft was nearing an unauthorized altitude or restricted area. Vehicle relationship to the planned groundtrack was also provided to the mission controller.

The advanced display must be easily maintained and operationally efficient. Software and hardware modifications such as adding new features or creating new maps with the plotboard system were difficult and expensive. The plotboard maps were unique because they were designed for particular requirements. As new aircraft are developed, new tracking areas must be defined and new maps generated. The old plotboards were outdated, and maintenance on these machines was difficult because replacement parts were no longer readily available.

## System Configuration and Capability

Display generation can be accomplished only after data are processed by the telemetry/radar acquisition and processing system (TRAPS, Fig. 4). The TRAPS consists of a triad of processors: two Gould 32/67s and a 32/97 integrated in a shared memory configuration. Data are converted to engineering units, stored to disk as well as shared memory for access by the many display programs in the MCC workstation environment. The communication path between the TRAPS and the workstation is through Ethernet using the Transmission Control Protocol/Internet Protocol (TCP/IP).

The real-time interactive graphics workstation consists of commercially available hardware with a custom application software package. A 32-bit UNIX-based graphics workstation is used for this application (Fig. 5).

The application software package that is the nucleus of the computer-generated mapping system is called real-time interactive map (RIM). It is an interactive program controlled by a mouse as well as by keyboard input. Data for generation of the display are derived from precision-tracking-radar data and downlink telemetry data.

Written in "C" language, the entire RIM package, including all database creation programs, consists of approximately 7000 lines of code. Effective structuring of source code was a high priority. This goal, along with the structuring provided by the C language, helped maintain readability and allows for easy enhancements. The main module of RIM controls the display and frame update. Approximately 20 subroutines provide the unique user requests for real-time computations or display requirements. In normal operation, RIM displays between 5 and 12 frames/sec.

The database for development of the map was accomplished using the established USGS (United States Geological Survey) and the DMA (Defense Mapping Agency) databases. These databases allow for implementation of the necessary detail to accomplish mission objectives. Current low-range plotboard maps in the Edwards area were digitized to provide the necessary detail not available on other databases. Software was developed to convert the different data formats of each source into a common structure. Once the data are converted to this common format, they are then converted to X-Y Cartesian coordinates, and scaled to feet. This database is easily modified to support additional mission requirements.

After the database is generated, rendering information is then added. This information instructs RIM how to display the data, either as lines, points, or filled surfaces. Information such as coloring, clipping, and hidden line removal is added. The data are also grouped together by feature to allow the RIM operator to select the level of detail desired for a particular flight.

During basic operations, the user selects the view and any other attributes desired. After this initial setup, RIM is ready for operation. By default, RIM displays a two-dimensional map. The trail of the aircraft is represented as a white line. This trail can be erased at any time by the user.

With the advent of complex, systems-driven vehicles, extreme demand is placed on the mission support team during real-time operations. With this in mind, it is important that the display system provide the data required and yet reduce the amount of human intervention. Many computations previously computed manually can be performed by RIM.

By a simple keyboard entry RIM can compute and update vehicle location in relation to any point on the map by providing a digital display (Fig. 6) of heading, deviation, distance in nautical miles, and estimated time of arrival (ETA) to that point. It also provides a digital readout of the vehicle's bearing and distance from both NASA and the Edwards tactical air navigation (TACAN, Fig. 7). This aids controllers when vectoring a chase aircraft to the test vehicle. Another feature allows controllers to overlay a compass rose over the vehicle (Fig. 8). This compass rose, marked in degrees, allows controllers to issue course corrections during flight. Figure 9 demonstrates a 2-min predicted flightpath feature. This feature, when enabled, displays a dashed line ahead of the aircraft. This line is marked every 30 sec and shows where the aircraft will be 2 min into the future. This line takes into account downlinked telemetry data and precision tracking data such as airspeed, pitch, roll, and rate of turn.

Other RIM features include monitor and display of predefined altitude restrictions for restricted areas and warning indication if the vehicle descends below these predefined restrictions. Users can enter such data as which restricted areas are "hot" (active), or "cold" (available). To ensure that aircraft stay within the boundaries of their assigned restricted area, users may instruct RIM to compute and display the distance from the aircraft to the nearest edge of the restricted area. A restricted area setup menu is provided (Fig. 10) to define these attributes of each restricted area. By reducing the amount of data that mission controllers have had to manually process, the new system allows them to better focus their efforts on monitoring the overall condition of the flight. All this helps improve the overall safety of flight testing.

A generic cockpit instrument display (Fig. 11) can be enabled to provide basic aircraft attitude information, heading, and altitude. This display will provide the mission controller with a realistic graphic display of actual cockpit instruments.

Figure 12 demonstrates the menu that allows the user to enable or disable map features. The operator can select levels of detail to be displayed on the map. By disabling certain map features, the map becomes less cluttered, and allows the operator to see only those points of interest. At any time the operator can "zoom" in or out on the map, as well as translate the map in any direction. These capabilities are also provided automatically by RIM, again reducing the amount of operator intervention required.

In addition, RIM makes use of the three-dimensional capabilities of the graphics workstation. By applying certain transformations to the map, we are able to simulate a view from either the cockpit (Fig. 13), an imaginary chase plane (Fig. 14), or the ground (Fig. 15). These views help visualize the aircraft's attitude and flightpath.

Color hardcopy of the RIM display can be obtained at any time in the mission. This is accomplished utilizing a D-scan, model CH-5312 color hardcopy unit. This unit provides an 8 by 10 in. color representation of the display. The user simply starts the hardcopy process by pressing a button located near the display. The video image is then captured by the hardcopy unit, where it is printed. The process of capturing the video image takes approximately 5 sec. The hardcopy unit then transfers this image to paper, which takes 30 to 40 sec.

## Future Applications

Still in evolutionary development, many graphics displays are being improved with features that will compute information critical to the mission. These features will include the ability to support research flight test missions in areas not currently incorporated in the database. This requires implementation of a global coordinate system capable of using GPS data.

A development effort is now in progress to incorporate topographical information into the database. This will provide another dimension to the display that will add detail and allow mission controllers to better visualize flight conditions in mountainous areas and during terrain-following missions.

Other enhancements will provide a capability to enter and display a predetermined flight plan. This will allow controllers to detect deviations from the proposed flight plan and will be particularly useful in trajectory guidance programs. System enhancements such as this will continue. System evolution is driven by the research test flight mission requirements.

A more powerful system than the model currently in use has been delivered and will increase system processing power by a factor of three and the graphics power by a factor of five. This will allow the WATR to increase the overall capability of the RIM display system.

## Concluding Remarks

Advanced displays developed by the WATR team continue to contribute to the success of NASA's aeronautics program. Mission productivity is enhanced with the development of advanced display systems such as RIM. The continuing challenge is to provide more research flight test information to the MCC in a form that will enhance mission effectiveness and reduce the potential for human error. With the power of the graphics workstation, RIM is an advanced capability that is easy to use, flexible, and provides a wealth of real-time information to support a mission. With this system, the WATR will continue to provide an effective and technologically advanced capability for the agency's aeronautics program.

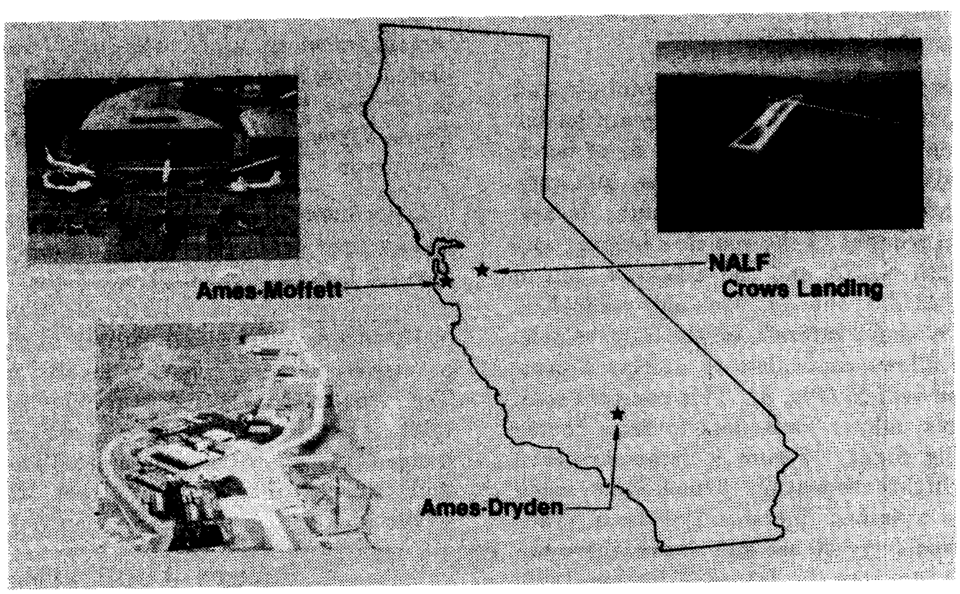


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*Fig. 1 NASA Ames Research Center Western Aeronautical Test Range.*

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*Fig. 2 Mission control center.*

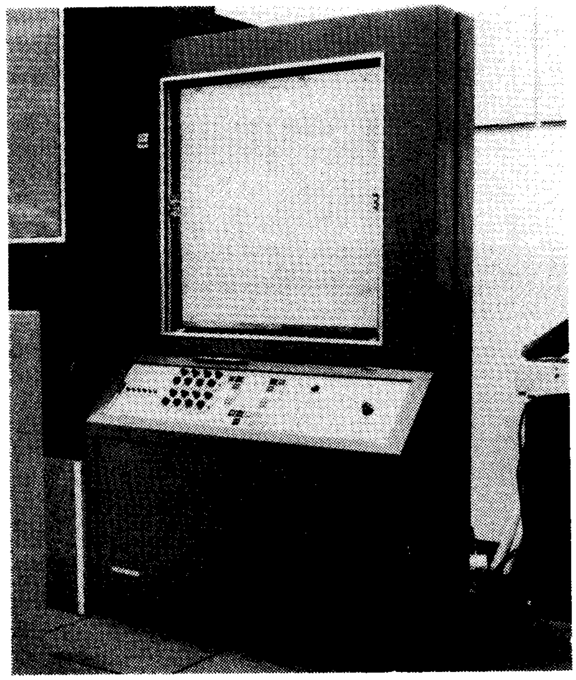

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*Fig. 3 Plotboard.*

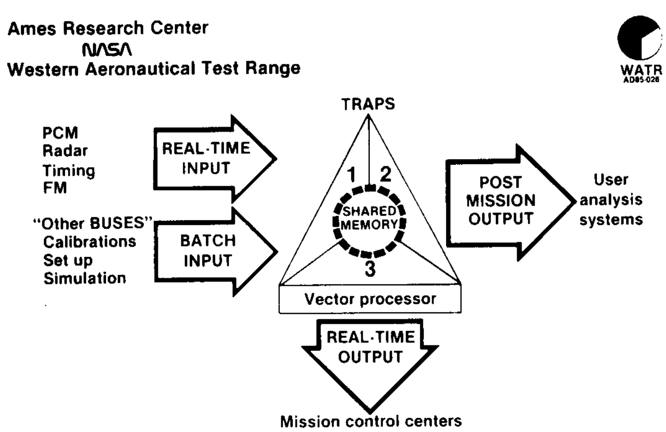


*Fig. 4 WATR telemetry/radar aquisition and processing system.*

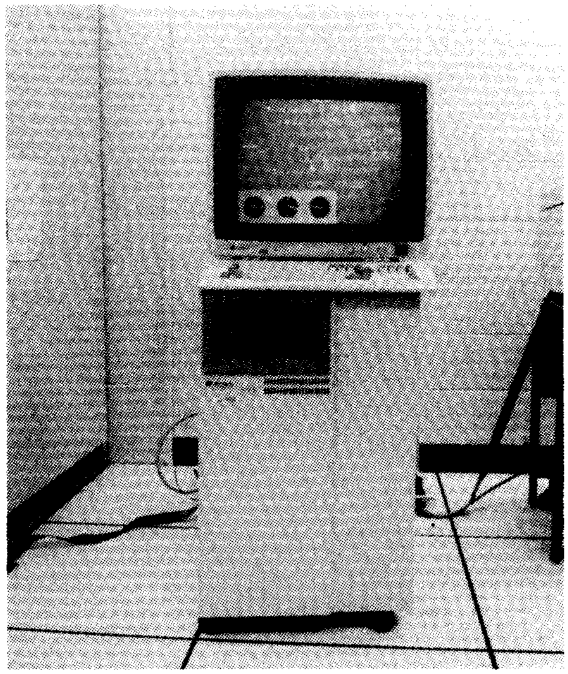

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***Fig. 5 RIM: top view.***

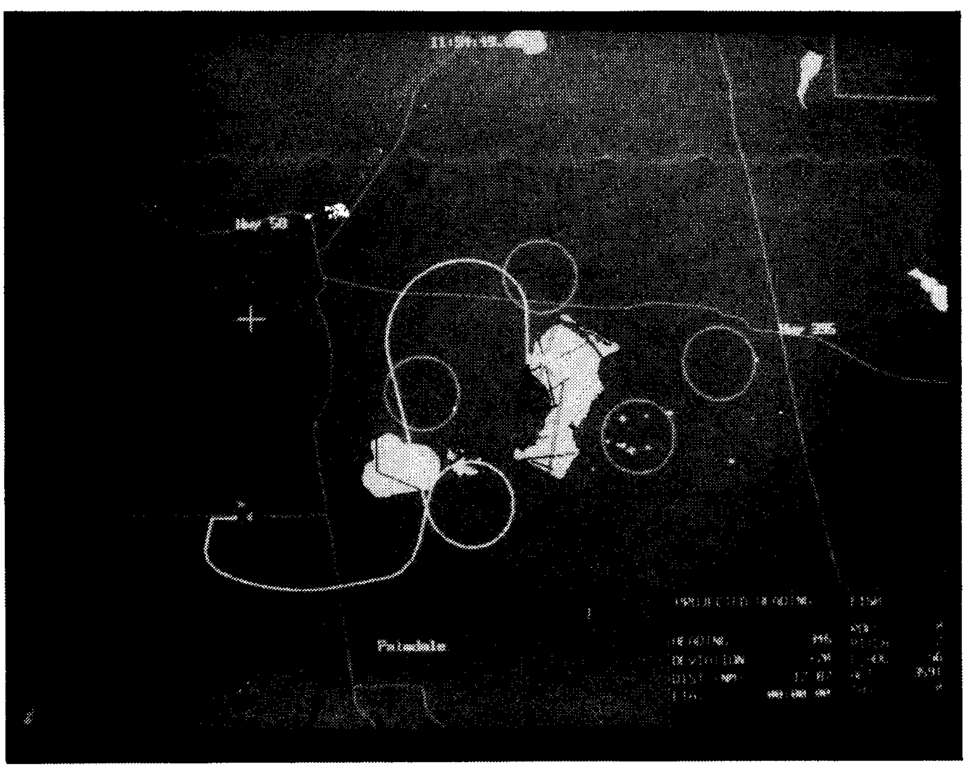

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***Fig. 6 RIM: projected heading.***

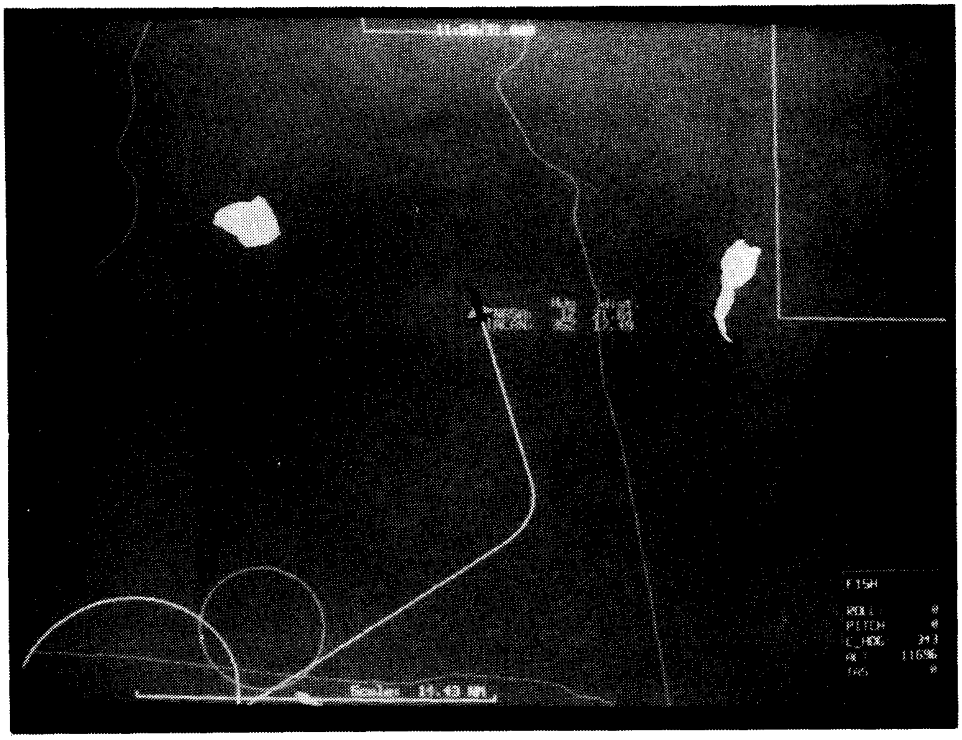

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***Fig. 7 RIM: bearing indicators.***

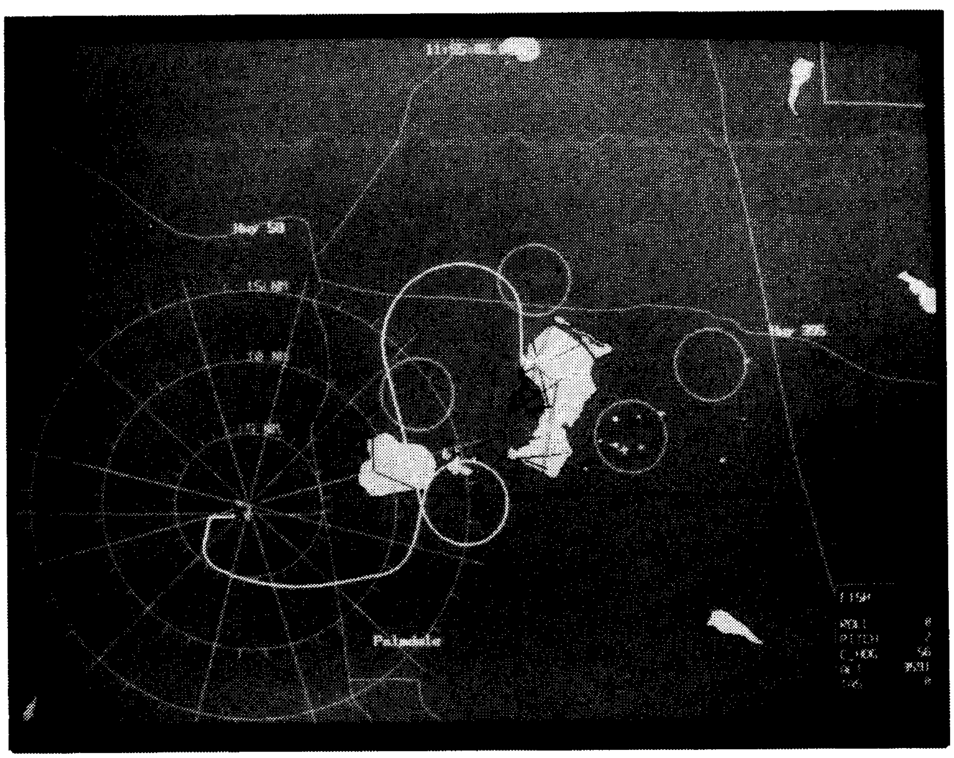

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***Fig. 8 RIM: compass rose.***

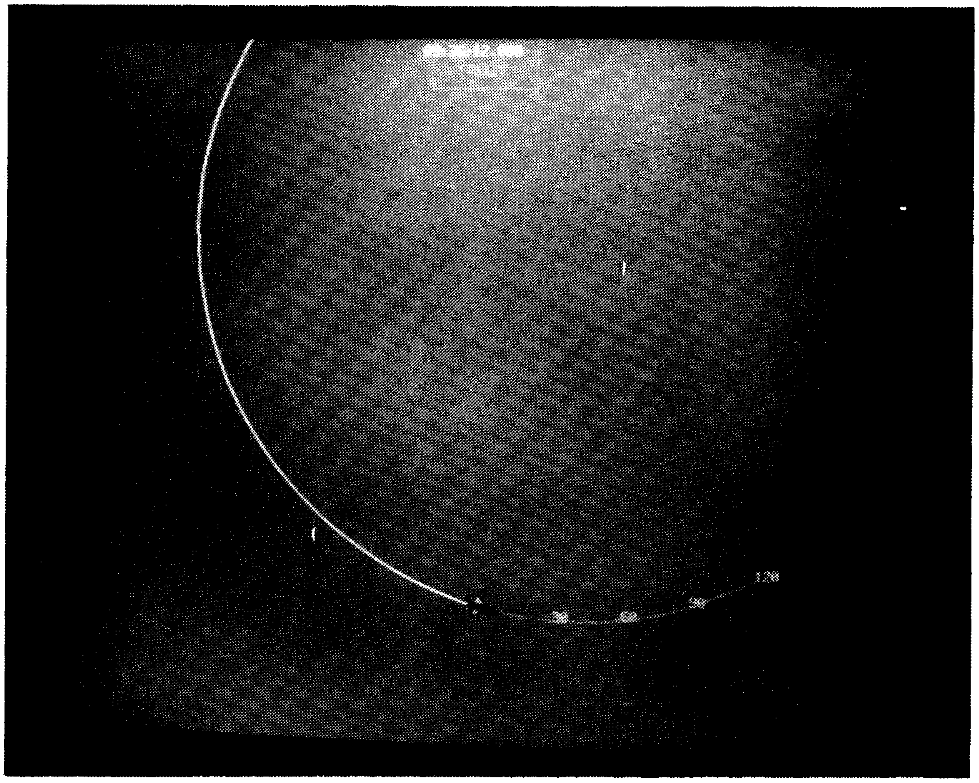

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*Fig. 9 RIM: 2-min predicted flightpath.*

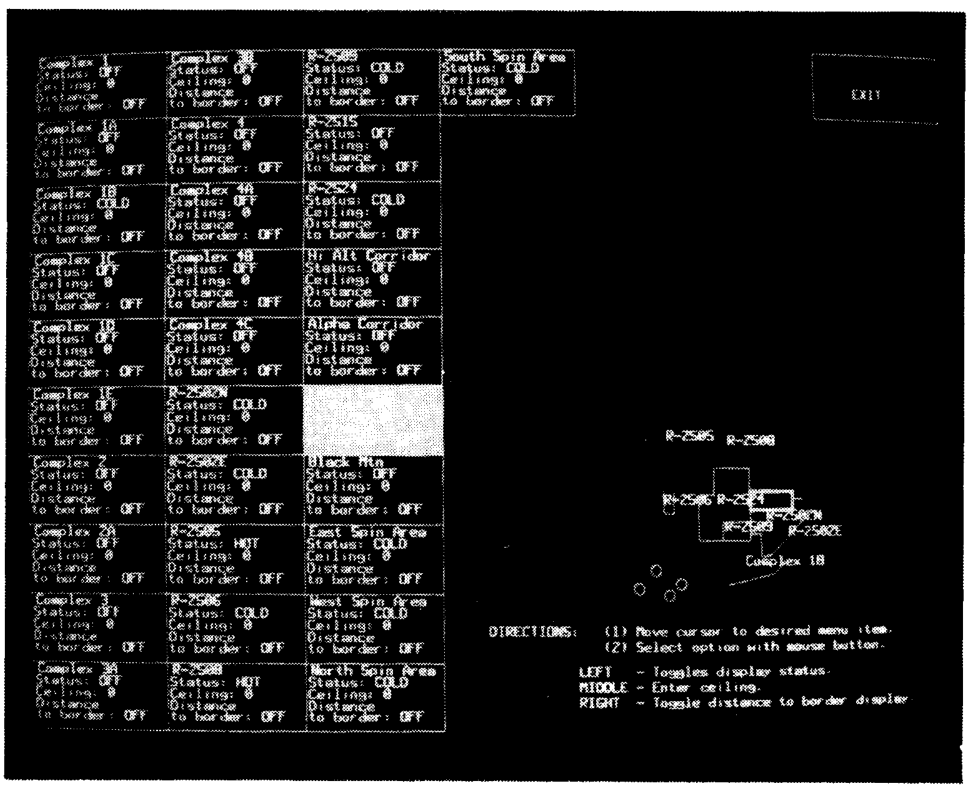


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*Fig. 10 RIM: restricted area setup menu.*

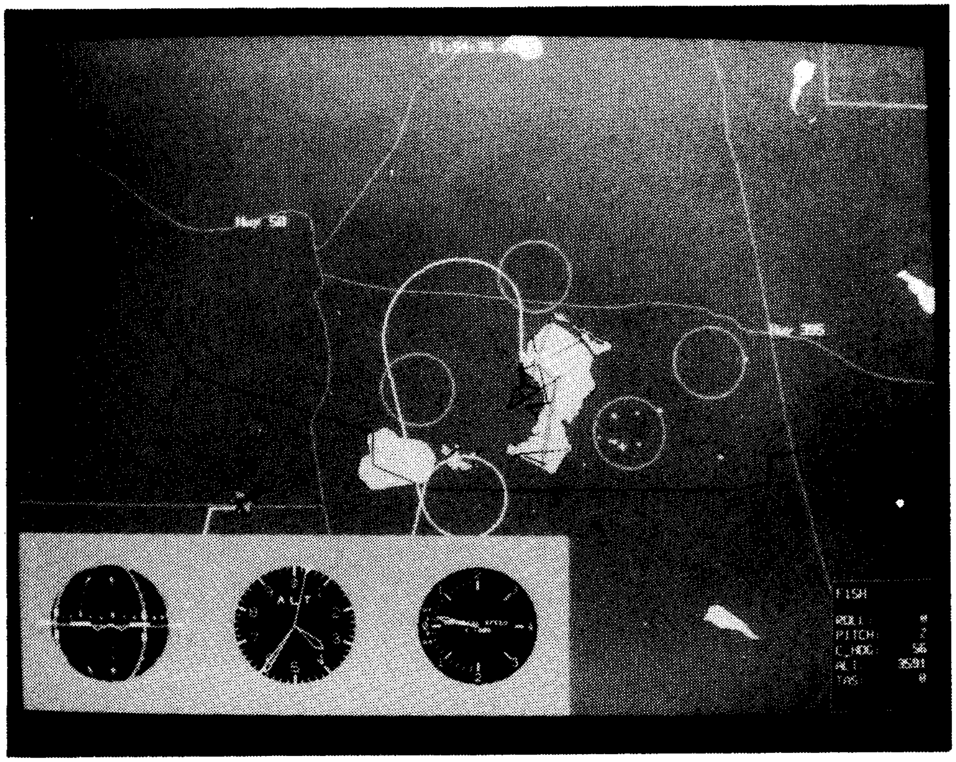


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*Fig. 11 RIM: cockpit instruments.*

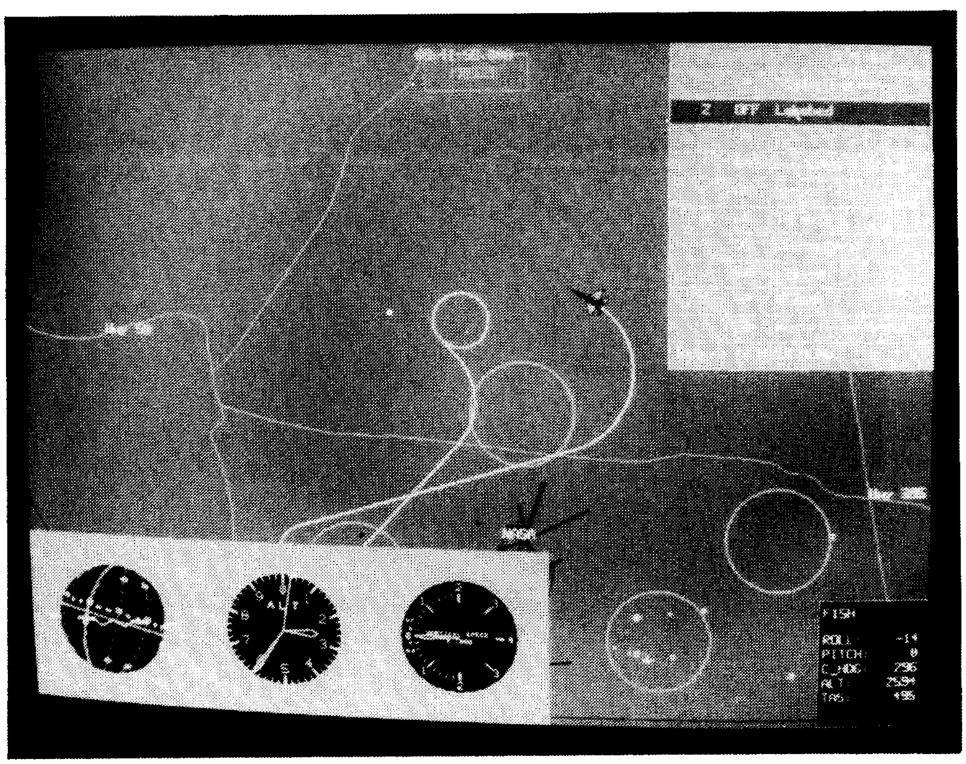


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*Fig. 12 RIM: main menu.*

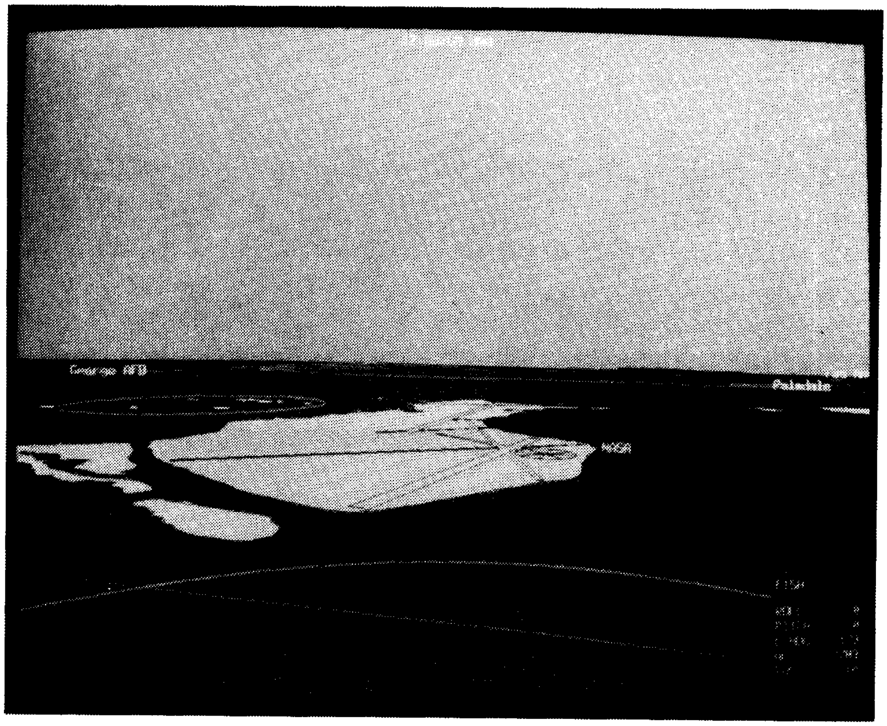


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***Fig. 13 RIM: cockpit view.***

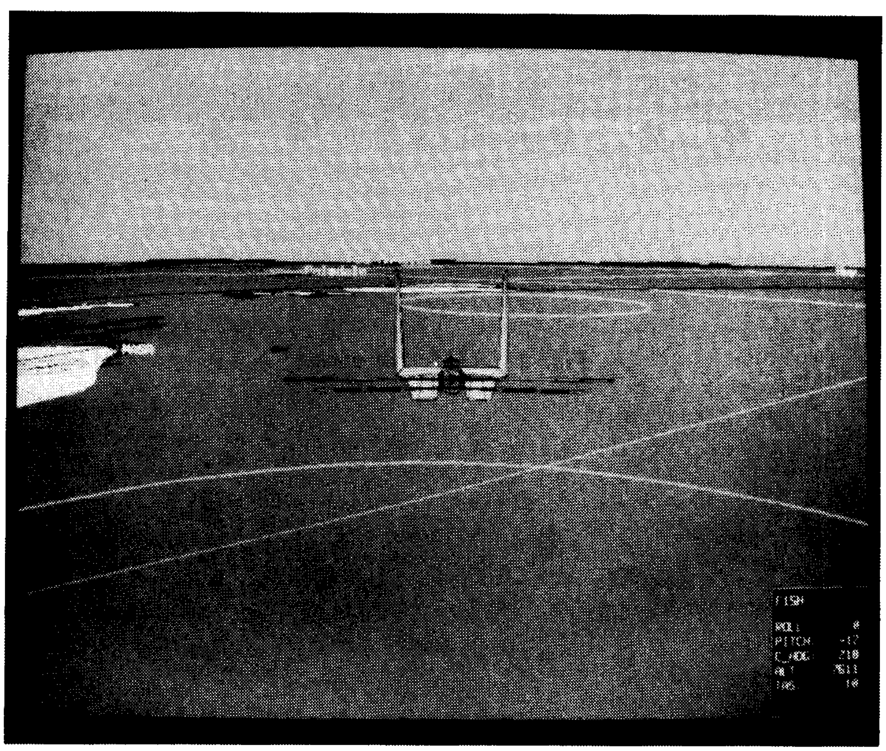


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***Fig. 14 RIM: chase view.***

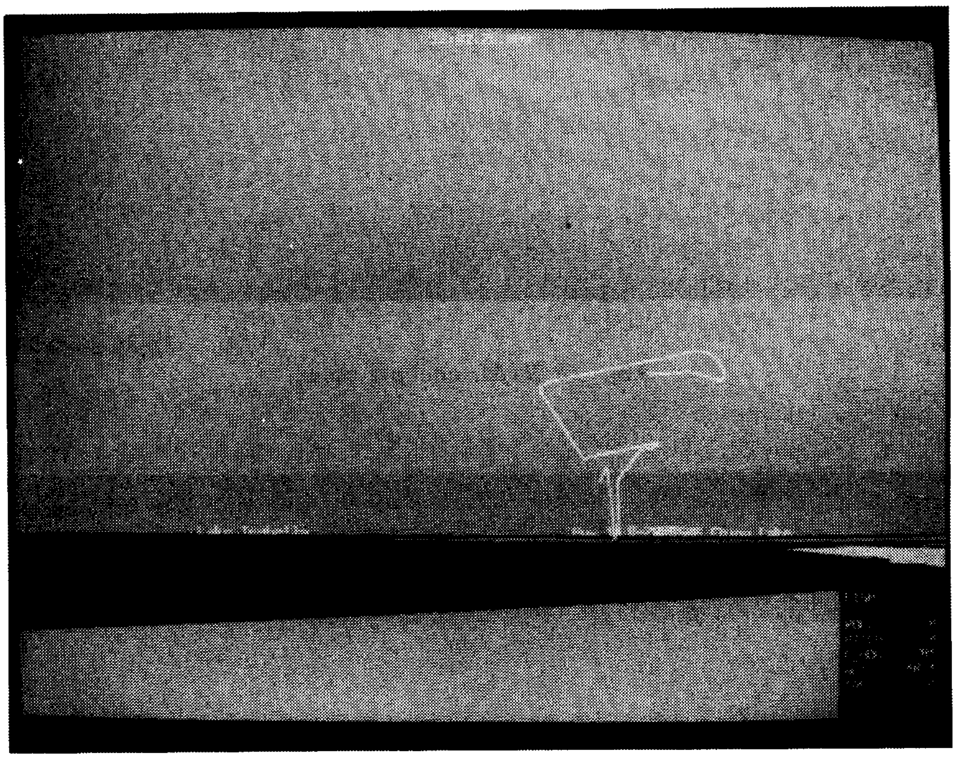

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***Fig. 15 RIM: 3-d view.***

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16. Abstract

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