A LOW-COST DISPLAY FOR SATELLITE MISSION PLANNING

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ABSTRACT

Current approaches for planning earth-viewing missions involve plotting and presenting data in many different forms. This approach is time consuming and fails to combine the necessary data (e.g., earth geomorphology, satellite viewing region, sun angles, and meteorological effects) in a common frame of reference.

The mission analysis planning system (MAPS) pictorially displays, in color on a back-lit screen, up to ten independent factors that influence mission decision making. Image intensity is controlled independently, and images can be superimposed on one another. The MAPS design is described, and some applications are presented.

INTRODUCTION

Planning of earth-observation missions involves analysis of many factors, including sun angles, cloud cover, satellite location, viewing constraints, and geomorphology. Viewing success is contingent upon many other mission-related factors such as communication with ground stations, proximity to data verification sources (i.e., other satellites), and location of areas directly related to the satellite mission objective (i.e., military areas of interest and political or demographic regions). The schedule of viewing opportunities for a long-term mission is best done with a computer program that verifies all viewing constraints and mission requirements. While this schedule provides a baseline for all mission planning, it defines only a point solution and fails to convey effectively visibility of the various orbital and mission interrelationships. The required visibility can be obtained by a large screen that graphically displays all the interactive mission elements. Thus the user can observe the overall conditions and, on an interactive basis, make adjustments, experiment with other conditions, and alter the baseline plan when more promising conditions are discoverd. In addition, as conditions change throughout the mission (cloud cover, snow and ice, objectives being accomplished, etc.), the display will permit evaluation of these changes and development of new plans by the user. Although the requirements for this display result from its application as a working analytic tool for missions planners, it can also provide an excellent display of mission conditions for educational or briefing purposes.

Requirements

Planning an earth observation mission requires individuals expert in at least four areas: phenomenology, meteorology, sensor analysis, and mission analysis. In addition, other persons may be needed, such as a Spacecraft subsystem specialist for a particular requirement. There may also be areas on the earth to be viewed in response to a particular information need. This would require a person familiar with that requirement to work with the mission planning team. Such planning would begin well in advance to sort through the stategies and feasible approaches for the data requirements and continue as actual, final real-time planning. Thus, the mission planning team is a multi-disciplinary team whose function is to plan observation opportunities that maximize the desired objectives of the viewing sensor, and concurrently, maximize the potential of successful data gathering.

A key element of the mission planning team is a large-screen display that is currently under development at the Space Operations/Integration & Space Systems Division of Rockwell International at Seal Beach, California. This display is known as the mission analysis planning system (MAPS) and is being sponsored by company internal research and development funds. MAPS can be used for all types of earth-observing satellite missions and may find applications in other areas of military and civilian planning. An infrared staring mosaic sensor that will fly on a satellite in 1983-84 will be the first application of the MAPS display.

Development of the MAPS display focused on two basic objectives: (1) providing a display that will be usable ad viewable by the mission planning team and (2) developing an approach that provides the information in the best possible format needed by that team. In other words, the goal was not to develop or exploit a particular area of display technology, but to meet a well-defined need with limited resources and equipment.

Three key requirements guided the MAPS development process: information, accessability, and registration.

Information--The primary reason for the display is to present the information required by the mission planning team. Initially this consisted only of a simple world map with a satellite ground trace overlay. It soon became apparent that geomorphic features were needed on the map and that a field of view and time were needed on the ground trace. As planning of mission scenarios progressed further requirements emerged. These are defined in detail under “Information Presentation.” Finally the increasing number of information types demanded development of specific techniques for their display. These techniques are also covered in the Information Presentation section.

Accessability--To be effective, the MAPS display must be a working tool of the mission planning team, not simply a static presentation of analysis results. It is to be a dynamic, interactive device that responds to the team's queries with portrayals of complex situations. If the display is to be interactive with the MAPS, it must have the following capabilities:

- It must be viewable to the team at all times. An individual standing in front of the screen must not block out the image on the screen.

- Images must have quick recall. Studies have shown that individuals will not use a system that does not respond promptly to queries. Loading of the data, computation, and setup of displays must all be rapid.

- Control of images must be easy; i.e., complex computer commands must be avoided. The use of joysticks, light pens, and analog controls is desirable.

Registration--The final major requirement was to combine all of the information on a common format or coordinate system. One approach is to plot the trajectories on a set of maps, observing LANDSAT photos and weather satellite photos and reading computer printouts of tabulated observation points. This fractionated approach is inefficient and time consuming and it often fails to uncover important relationships in the data. It was therefore rejected, and the decision was made to map all the information onto the same projection. Because the initial application involves observation of the northern hemisphere only, a polar projection of the northern hemisphere was selected as the common format. Finally, all of the images must be projected onto the display in the correct alignment--registration. This, of course, ensures the technical accuracy of the information source.

With the key requirements established, an implementation approach was needed. A number of approaches were considered, including:

- Computer CRT display
- Large-screen computer-driven display
- Plasma and liquid crystal displays
- Light tables
- Film image projection

While the selected approach relies primarily upon film image projection, it draws upon most of the others in some way.

INFORMATION PRESENTATION

An initial requirement of the MAPS display was that the screen be visible and usable by the mission planning team; thus the requirement to project the images onto the back side of the screen. With this requirement established, a layout of an entire room was made, containing the display, projecting equipment, support areas, and user areas (Figure 1).

Although MAPS was to serve primarily as a working tool, it can be seen from Figure 1 that it is a convient medium for large conference presentations.

The MAPS format resulted directly from the requirements previously described. Use of film images for display resulted from the needs for rapid recall of information and maximum information content. A high-resolution film image can be recalled in virtully zero time, whereas a high-resolution cathode-ray-tube (CRT) picture may take several minutes. In addition, even the most advanced CRT’s present orders of magnitude less information and are orders of magnitude more expensive. Of course, the CRT offers greater flexibility, with its image transformation and enchancement capability as compared to a film that presents a static image. In the MAPS, 35-mm projectors and overhead projectors will be used.

Several key features contribute to the effectiveness of the MAPS display: separate projection; blacking out of irrelevant data; and using color. It’s impossible to sort out the information when all images are presented simultaneously. Consequently, a separate projector is provided for each, allowing independent selection and intensity control. Thus only the desired combination of images appears and in the desired relative intensity. Figure 2 shows two such independent images.

Blacking out the regions without information content allows images from other information sources to predominate. The use of color increases the information content of the display by more than an order of magnitude.

Many kinds of images may be found desirable for various applications. Those under current consideration are:

1. Geomorphic map - contains terrestrial features such as vegetation and elevation, keyed by color.

2. Specific area map - contains greater detail of the geomorphic map for a particular area of interest (e.g., types of ice in the arctic region).

3. Outline map - shows only a clear geographic area against a black background, which permits superposition of other images.

4. Satellite ground visibility region - region changes with each orbit about the earth, and image rotates correspondingly.

5. Ground stations - outlines geographic locations in which the satellite can communicate with the ground.

6. Geographic grid - shows latitude and longitude.

7. Site locations - presents outlines of specific locations of interest to the mission planners.

8. Solar angle contours - defines sun elevation angles, day/night terminator, and local times of day. Since these vary with time, as does the satellite ground visibility, the image is rotated to correspond to the time of interest.

9. Cloud image - depicts cloud data as received from the geostationary observation environmental satellite (GOES) (discussed further in the next section).

This is a minimum set of images for an earth-observing, satellite mission planning team; others could be added for this and other applications.

SPECIAL PRESENTATION

Computer-Generated Images

While the MAPS display relies upon the film image as its primary source of information, a general-purpose desk-top computer with CRT graphics is used to develop some of the film images that constitute the MAPS primary source of information. A computer can perform coordinate transformation and image processing with relative ease. An example is in generation of images of snow and ice regions. The National Oceanic and Atmospheric Administration (NOAA) publishes a weekly map defining snow-cover regions with reflectivity as well as sea ice limits. This map can be entered into a computer with a conventional digitizer such as a light pen or stylus board. The data can then be transformed to the proper coordinate system that corresponds to the current application of MAPS. The tranformed map is then displayed on a CRT, and a 35-mm picture is taken for subsequent projection. Another powerful application of the computer is correcting for the inherent distortion of the MAPS display.

Image Distortion Compensation--Since MAPS uses multiple, independently projected images, distortion occurs when the projector line of sight is not normal to the screen. Two approaches are available. One is to incorporate the correction in the computer-generated image. A 35-mm slide is made of the image as it appears on the computer CRT. The second approach is to incline the image with respect to the optics throught which it is being projected. A 35-mm picture will then result in a distorted picture that again will be corrected when it is projected. When the projector line of sight is not normal to the screen, some of the image will be out of focus. In the current application, this effect is minimal.

Cloud Imaging--The presence of clouds can severely, impair data collection and in some instances render the data completely worthless. In both military and civilian planning, the forecasting of clouds and weather is a formidable but important task. One of MAPS major features presents cloud images in real time.

The primary source of data is the NOAA satellite known as GOES. Two of these satellites currently serve the western hemisphere: GOES East over southern Columbia, and GOES West at 135 degrees west longitude in the eastern Pacific. Figure 3 illustrates their composite viewing region.

The GOES transmits both visible and IR images of the earth twice an hour. The image data are received at Suitland, Maryland, and sent to regional distribution centers. The public has access to these data via a service known as a “GOES tap,” whereby an analog signal of the cloud picture is received over a telephone line. Figure 4 illustrates the procedure for receiving the signal and producing an image of the cloud.

The AM signal of the cloud image must first be demodulated to produce a line-by-line analog voltage equivalent. The analog signal is digitized by an analog-to-digital (A/D) converter, and the digital equivalent is stored in the computer. The computer performs the necessary coordinate conversions so the final image is produced in the same projection as all the other images used by MAPS. Thus an orthographic view from the equator, as taken by GOES, can be tranformed to a polar projection of the northern hemisphere. The GOES tap system produces one complete picture every half hour, as required by MAPS. As each picture is assembled in the computer, a 35-mm slide is made of the transformed cloud image. Thse slides can then be placed in separate projectors and sequenced to obtain cloud motion animation. Besides the GOES tap, other satellites provide cloud image data. These satellites are in polar orbits, which provide excellent views of cloud cover over the polar regions, where the quality of the GOES cloud image data is considerably reduced. The combination of these two sources of data ensures complete cloud information for MAPS.

Results

A MAPS prototype is under development at Rockwell International, Seal Beach, California. Various projection techniques, color combinations, and planning concepts are being evaluated. Figure 5 illustrates a typical display with three independently projected images: northern hemisphere map, grid, and satellite ground track.

The satellite ground track (shown as a narrow diagonal stripe) represents the viewable region of the earth for a specific orbital revolution. The mission planning team can study this region and define the specific scenes to be viewed. The viewing of scenes can be scheduled for efficient use of spacecraft resourcs (e.g., electrical power) and the time of the mission planning team. The satellite ground track can be rotated to other positions of interest to explore additional viewing possibilities. Image intensities can be adjusted to create the desired mix. After the viewing schedule has been selected, the ground station images can be studied to schedule the transfer of information to and from the satellite.

As discussed, the MAPS display of near-real-time cloud images is a significant advancement in display technology. Figure 6 illustrates the approximate coverage of GOES East, with an example of the cloud imagery. Reducing the intensity of the other displayed images allows clouds of varying types to be observed. In addition, cloud motion can be achieved by sequential selection of the projection devices.

The cloud animation, together with other meteorlogical data, will provide a forecasting capability that will greatly facilitate the scheduling of observation opportunities.

Summary and Conclusions

The mission analysis planning system (MAPS) is a 36-square-foot back-lit screen system currently under development at Rockwell Intenational. It has been effectively used in advanced mission planning of earth observing satellites. Images presented on the screen are derived from conventional map data as well as from computed data. The use of 35-mm colored slides increases the information content of the display and provides an aesthetically desirable presentation. Satellite viewing regions and sun conditions are animated by rotating transparencies on overhead projectors. Cloud-cover animation is achieved by sequencing 35-mm cloud-cover slides obtained by GOES’s. A simple panel allows the user to select and position the images and control their intensity.

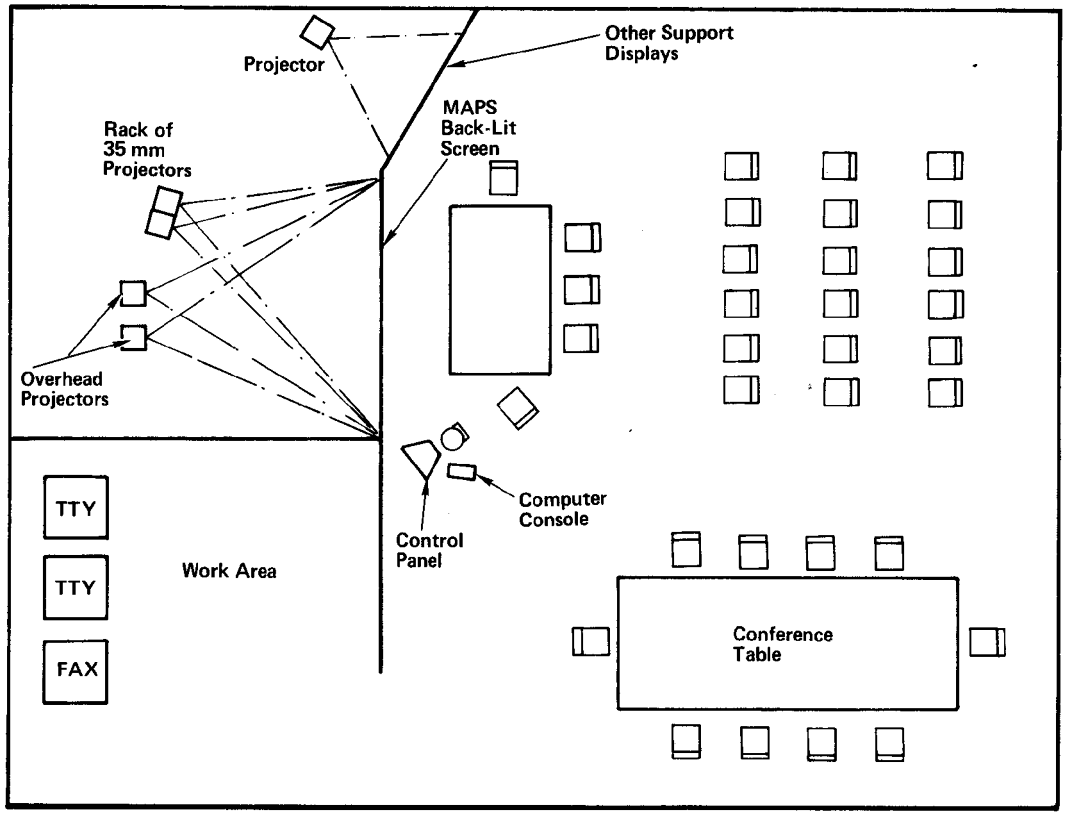

Figure 1 - Mission Analysis Planning System (MAPS) Control Center

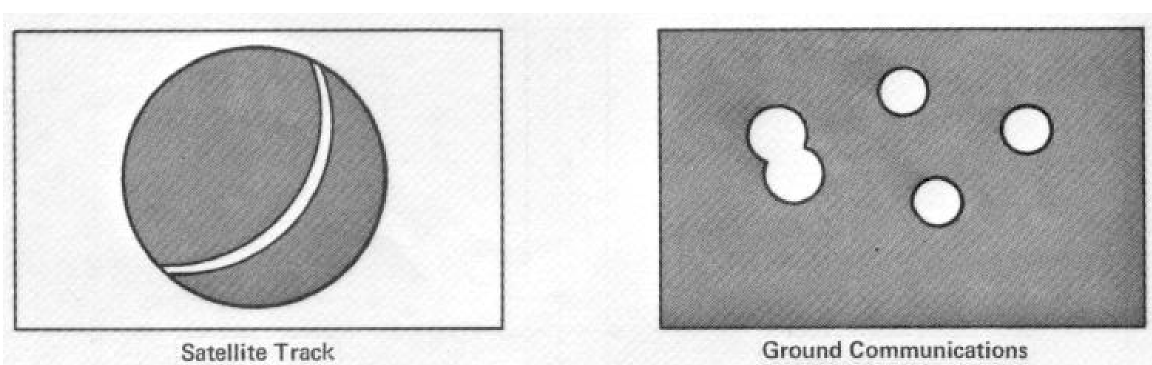

Figure 2 - Two MAPS Images

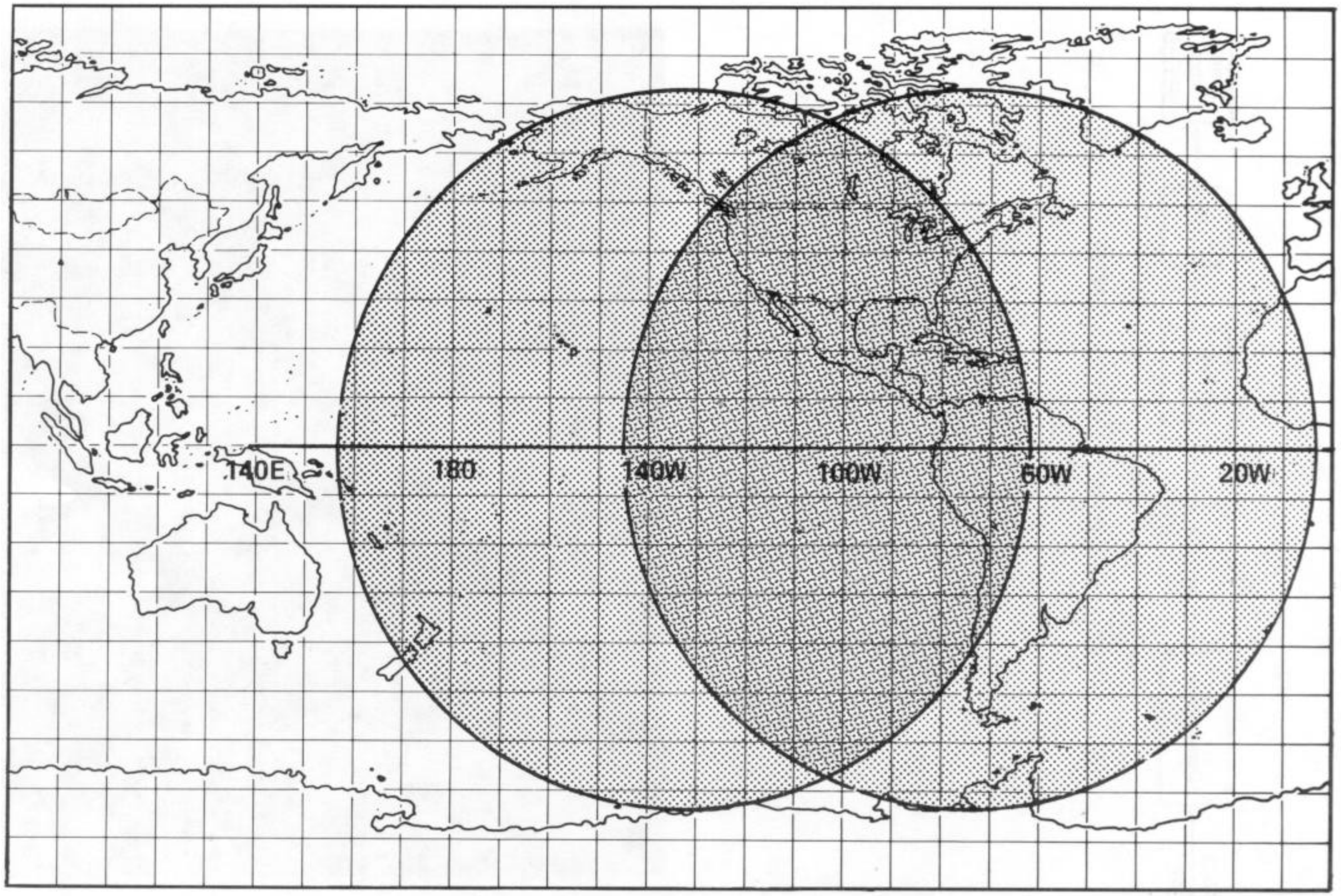

Figure 3 - Approximate GOES Viewing Region

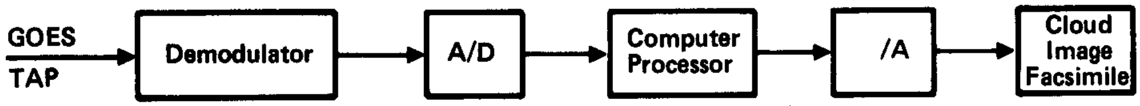

Figure 4-Cloud Image Production Block Diagram

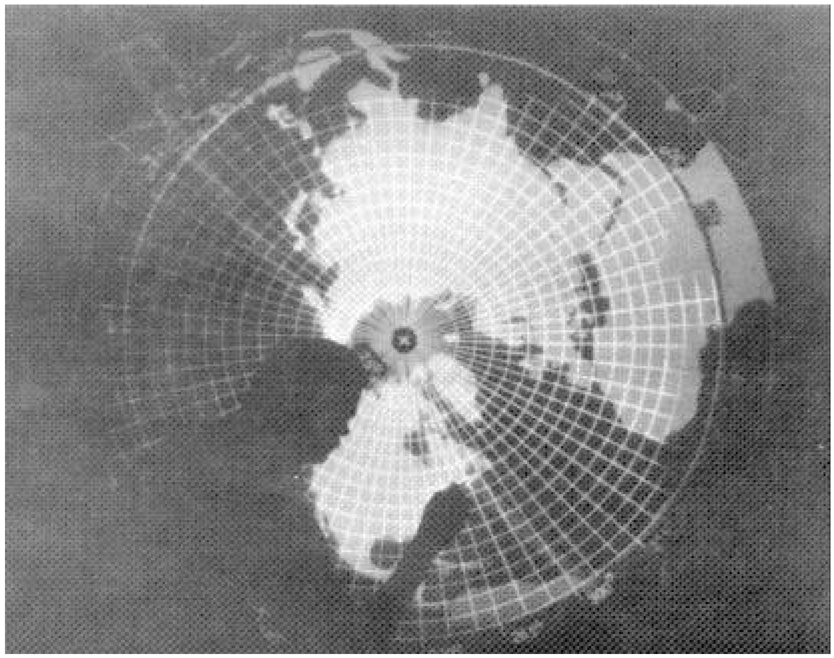

Figure 5-MAPS Example Display

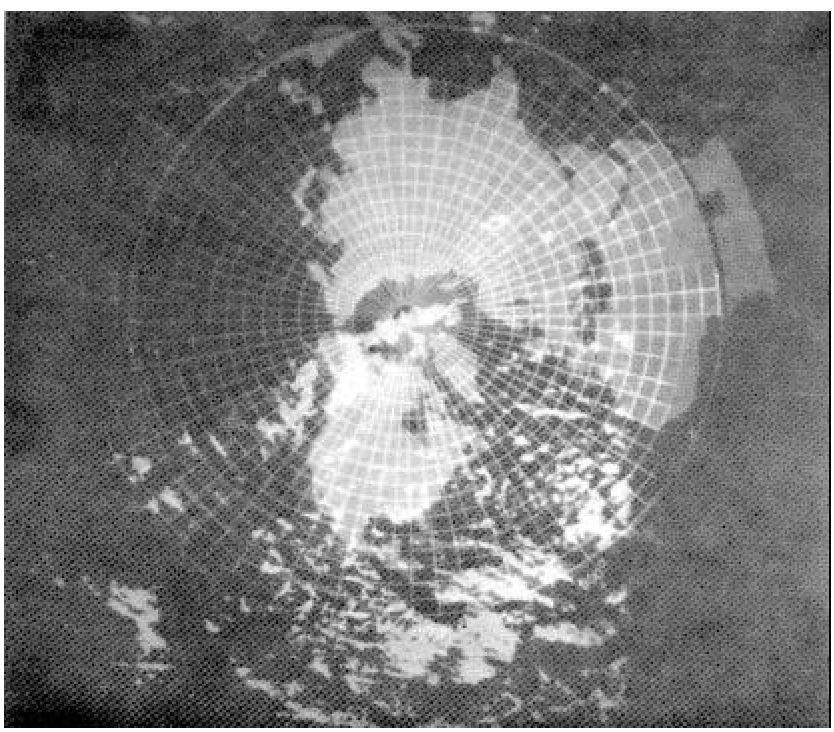

Figure 6-MAPS Display of Clouds