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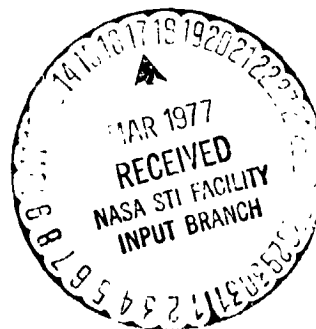
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UTILIZATION OF SATELLITE IMAGERY BY IN-FLIGHT AIRCRAFT

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15. SUPPLEMENTARY NOTES This report was prepared under the technical monitorship of Mr. Dennis W. Camp of the Atmospheric Sciences Division, Space Sciences Laboratory, NASA-Marshall Space Flight Center.					
16. ABSTRACT <p>A study was made to assess present and future utilization of satellite weather data by commercial aircraft while in flight. Weather information of interest to aviation that is presently available or will become available with future geostationary satellites includes the following: severe weather areas, jet stream location, weather observation at destination airport, fog areas, and vertical temperature profiles. Utilization of this information by in-flight aircraft appears especially beneficial for flights over the oceans or over remote land areas where surface-based observations and communications are sparse and inadequate.</p> <p>From this study it was determined that satellite meteorological data will have significant utilization at airline meteorology offices and by aircraft flight crews while enroute. Facsimile transmission of high quality/high resolution satellite images to aircraft will provide near-real time weather information upon which a flight plan modification can be based. Charter, corporate, and supersonic transports may justify the utilization of satellite images from a cost and safety viewpoint if a low-cost facsimile recording system can be designed for aircraft application.</p> <p>A feasibility program is proposed to evaluate transmission of satellite images using radio frequencies to an in-flight aircraft. The program is intended to evaluate the technical feasibility of high-quality facsimile transmission as well as to assess the utilization of satellite images by an enroute pilot under various weather conditions.</p>					
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FOREWORD

The idea for aircraft utilization of satellite data originated as a result of exploratory studies of potential uses of meteorological data from satellites by members of the Aerospace Environment Division (now the Atmospheric Sciences Division), Space Sciences Laboratory, the Marshall Space Flight Center (MSFC). The concept was developed during discussions by University of Dayton Research Institute (UDRI) personnel and Mr. Dennis Camp of MSFC with Mr. Ed Rich of the National Oceanic and Atmospheric Administration/ National Environmental Satellite Service (NOAA/NESS) and Mr. Paul Kadlec of Continental Airlines.

The research was conducted by the University of Dayton Research Institute for NASA-George C. Marshall Space Flight Center under the technical direction of Mr. Dennis Camp of the Space Sciences Laboratory. The support for this work was provided by Mr. William McGowan of the Aviation Safety Technology Branch, Office of Aeronautics and Space Technology (ROO/OAST), NASA Headquarters.

AUTHOR'S ACKNOWLEDGMENTS

The author would like to express his appreciation to Mrs. Fran Parmenter of the Applications Group of the National Oceanic and Atmospheric Administration/National Environmental Satellite Service (NOAA/NESS) for providing both the satellite images (Figures 1 through 3) and the meteorological interpretation of these images. She also offered several editorial suggestions which were incorporated into the report.

Mr. Dennis Camp of MSFC provided direction relative to the contents of this report and actively participated as a NASA representative in nearly all conferences and discussions pertaining to this work. The author gratefully appreciates his contributions to this work.

A preliminary presentation of the concepts explained in this report was made to the Meteorological Committee of the Air Transport Association in Atlanta, Georgia. Discussions with meteorologists from the various airlines influenced the contents of this report and provided insight into the airlines point of view. The cooperation and information provided by these people are gratefully appreciated. Mr. Paul Kadlec, Manager of Meteorology for Continental Airlines, deserves special thanks for his assistance in planning a program to test the feasibility of facsimile transmission of satellite images.

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SECTION 1

INTRODUCTION

Geostationary meteorological satellites have made available a wealth of imagery data to the meteorological community. The Synchronous Meteorological Satellite/Geostationary Operational Environmental Satellite (SMS/GOES) presently in existence provides visual and infrared images of the earth at time intervals of thirty minutes. Present coverage with East and West GOES extends from the western tip of Africa in the Atlantic eastward to New Zealand in the Pacific. This region includes the North and South American continents and Pacific Islands to 30° west of Hawaii. Within the next few years, additional launches of geostationary satellites are planned by European and Asian countries to provide worldwide visual and infrared images from a vantage point along the equator 35,800 km above the earth's surface. Observations from these satellites provide useful data between 60° N and 60° S latitudes.

Images from the presently orbiting U. S. East and West GOES satellites are transmitted to the National Oceanic Atmospheric Administration/National Environmental Satellite Service (NOAA/NESS) for processing and sectorizing. Sectorizing consists of extracting various geographic areas from the full disk image and transmitting this information to users throughout the United States. Maximum resolution available from the sectorized image is one-half mile for visual and four miles for infrared images.

Skillful interpretation of SMS/GOES satellite images can provide valuable information concerning ongoing meteorological events. Presently, satellite images are especially useful for observing areas of severe weather, such as thunderstorms, squall lines, tropical storms, hurricanes, and other weather phenomena. Also, observations of cloud motion through animation of sequential images allow small cloud elements to be used as tracers from which wind velocities at the cloud level can be inferred.

Jet stream location along with the accompanying areas of turbulence, in sharp curvature regions, can be analyzed from cirrus cloud formations. The infrared images can be utilized to determine cloud top temperatures or, for the areas where clouds are not present, surface temperatures. Cloud heights are estimated from cloud temperatures by referencing to rawinsonde temperature altitude profiles.

The satellite imagery data available from the GOES satellites have not been fully utilized by the aviation community. Presently, only a few airlines receive any satellite facsimile images, and those who do, receive only very limited observations. The quantity and quality of data available from geostationary satellites suggests that better utilization of these data by the aviation people is possible. One application would be the facsimile transmission of interpreted satellite images to enroute aircraft. The real time availability of satellite images to a pilot should be beneficial. It would assist him in modifying his flight path, if necessary, for reasons of improved fuel economy, increased passenger comfort, and/or enhanced aviation safety. Pilot experience, as occurred with the now conventional onboard weather radar units, will certainly produce added operational value for satellite images in terms of improved flight path confidence, etc.

A few potential aviation applications of the present SMS/GOES data, with particular emphasis on near-real time facsimile reception onboard aircraft, are discussed below.

SECTION 2

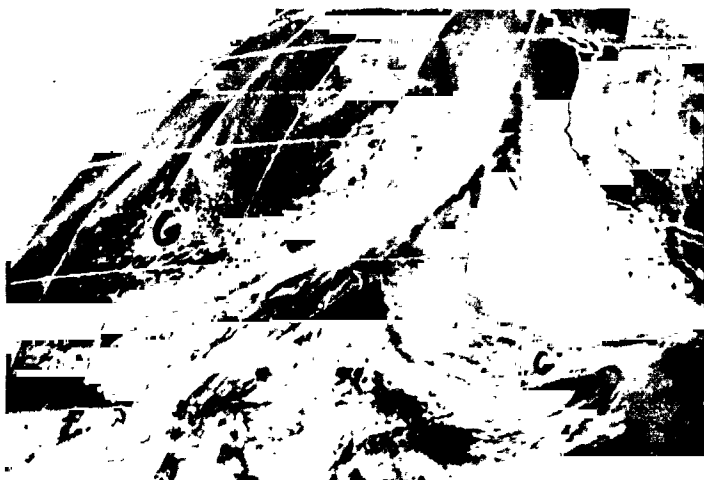
JET STREAM

The location of the jet stream is an important economic consideration for commercial aviation. Whenever possible, aircraft flying west to east try to have a flight plan which is designed to take advantage of the jet stream. The alignment of an aircraft near a jet stream core for even a small segment of flight can result in a direct cost savings in fuel consumption. Refinements in the knowledge of the jet stream alignment can be made with the assistance of winds measured by an aircraft equipped with an Inertial Navigation System (INS). A monitor of wind variability when entering a jet stream core can be helpful in obtaining the maximum wind velocity in the jet and can be used as a direction finder in maintaining orientation with the jet. Not to be overlooked, however, is the practical problem of filing a revised flight plan each time a deviation is desired.

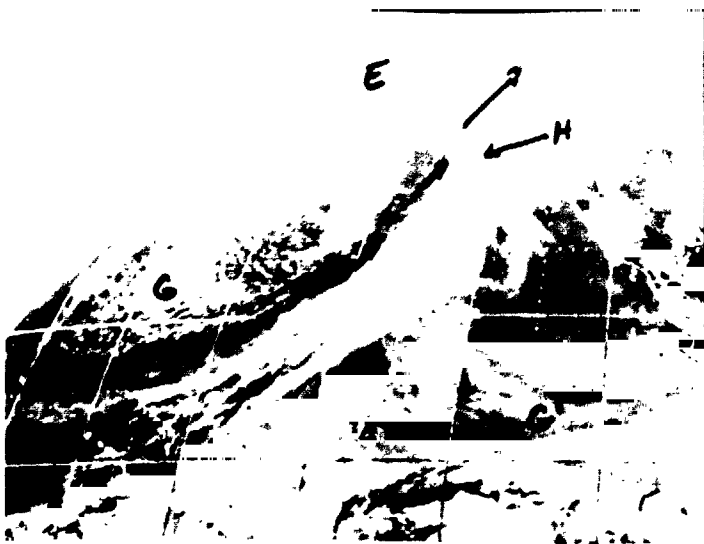
Of equal importance to an aircraft is the avoidance of strong headwinds originating from a jet stream when traveling in a westward direction. When the need to penetrate or cross a jet stream core is present, the time spent in adverse headwind conditions can be minimized by choosing a favorable direction of crossing.

The location of both polar and tropical jet streams can often be observed from satellite images of cloud formations. Figures 1a, 1b, and 1c show visible, infrared and enhanced infrared images at four miles resolution of the eastern Pacific from Honolulu to the western coast of the United States.

The views shown are simultaneous sets of data taken from the two sensors onboard the SMS-2 (Pacific) satellite. They show a large frontal system stretching from the Gulf of Alaska (E) to just north of the Hawaiian Islands (F). Of particular interest to commercial aviation are the convective regions within the frontal band, the location of high-level clouds, and the upper-level flow or wind field.



a. Visible imagery
4 mi. resolution



b. Infrared imagery
4 mi. resolution



c. Enhanced infrared
imagery 4 mi. resolution

Figure 1. SMS-2 2045 GMT, November 18, 1975.

The infrared (IR) views (Figures 1b and 1c) quickly show the relative height of the clouds. For example, the large areas of cloudiness, G and G', are low stratiform elements; the clouds near (E) are middle altostratus bands; while the rest of the frontal band is composed of a thick mixture of low, middle, and high cloudiness. In the final IR view (1c) the clouds are contoured according to temperature. Note that the coldest clouds are located at (H).

Also superimposed on the images is the axis of the jet stream as determined from the picture. The maximum winds are usually located poleward of the abrupt edge of the cirrostratus cloud deck. Data such as these allow the user to obtain a fix on the maximum wind axis at an intervening time between the 0000 GMT and 1200 GMT map analyses, and to utilize this data to plan an optimum flight track. These data also serve to graphically display the type and aerial coverage of cloudiness along the flight route and can make the pilot aware of the weather changes that might occur at the destined terminal before touchdown.

The wind speed in the jet stream core could be greater than 50 knots above the wind speed along the periphery. The advantage of an additional 50 knot tailwind over a two-hour period would result in a time saving of ten to fifteen minutes. On a wide-body aircraft where direct operating costs are on the order of \$2500 an hour, a fifteen-minute time saving would save over \$500 in operating costs. In addition, indirect operating costs would be reduced by providing additional revenue-producing flights before scheduled maintenance. For international airlines that are constantly exposed to the economics associated with jet stream conditions, in-flight utilization of satellite imagery may be justified on fuel economy alone.

Turbulence associated with a sharp curvature of the jet stream can often be observed on satellite images. Studies have shown that moderate to severe turbulence occurs with certain meteorological synoptic patterns. One area where significant turbulence is found is that which lies poleward of a sharply anticyclonically turning jet axis. In this area, such as (A), Figure 2, the winds tend to overshoot and the mixture of directional and

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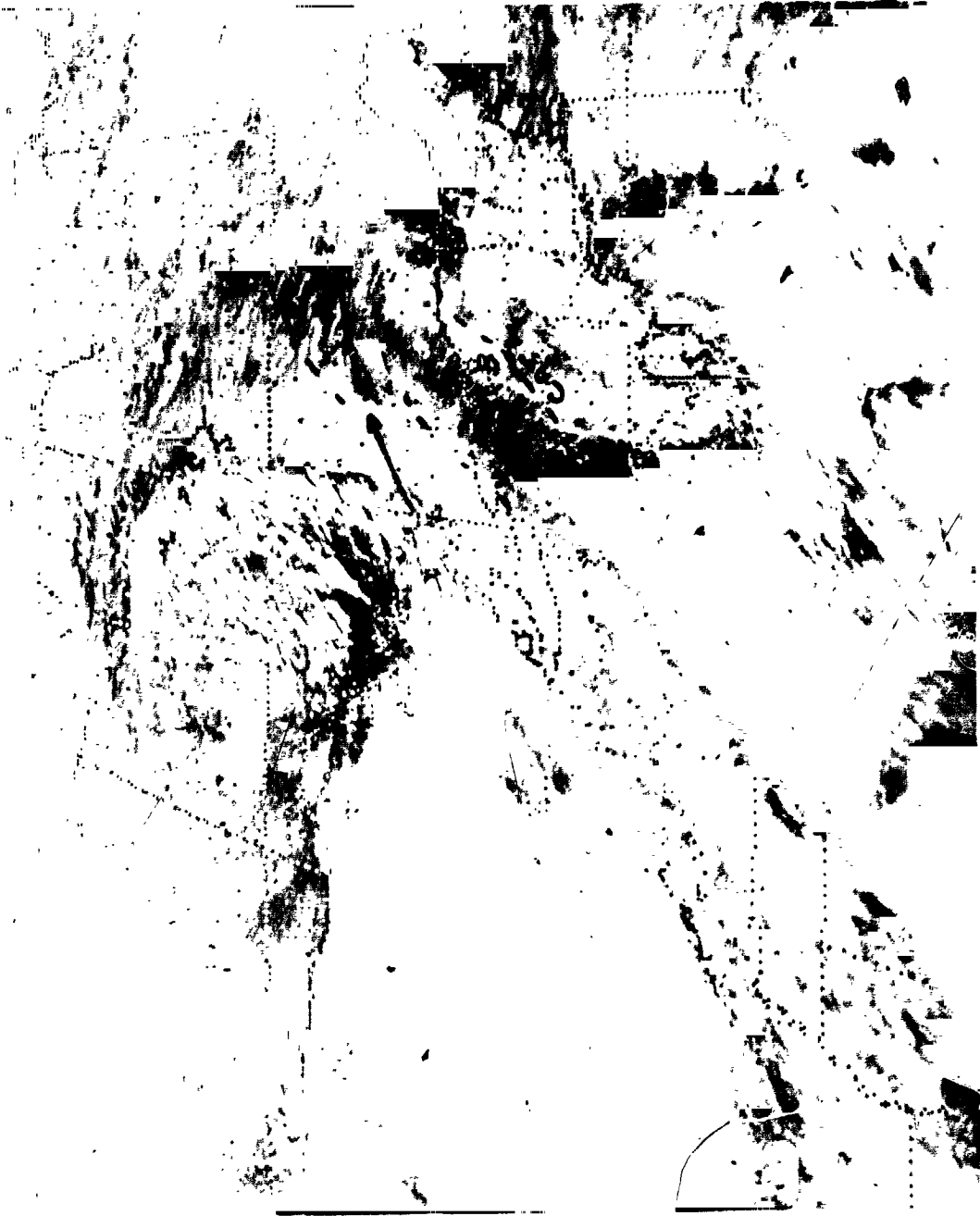


Figure 2. SMS-1 visible data (1 mi. resolution), 1630 GMT 25 October 1975.

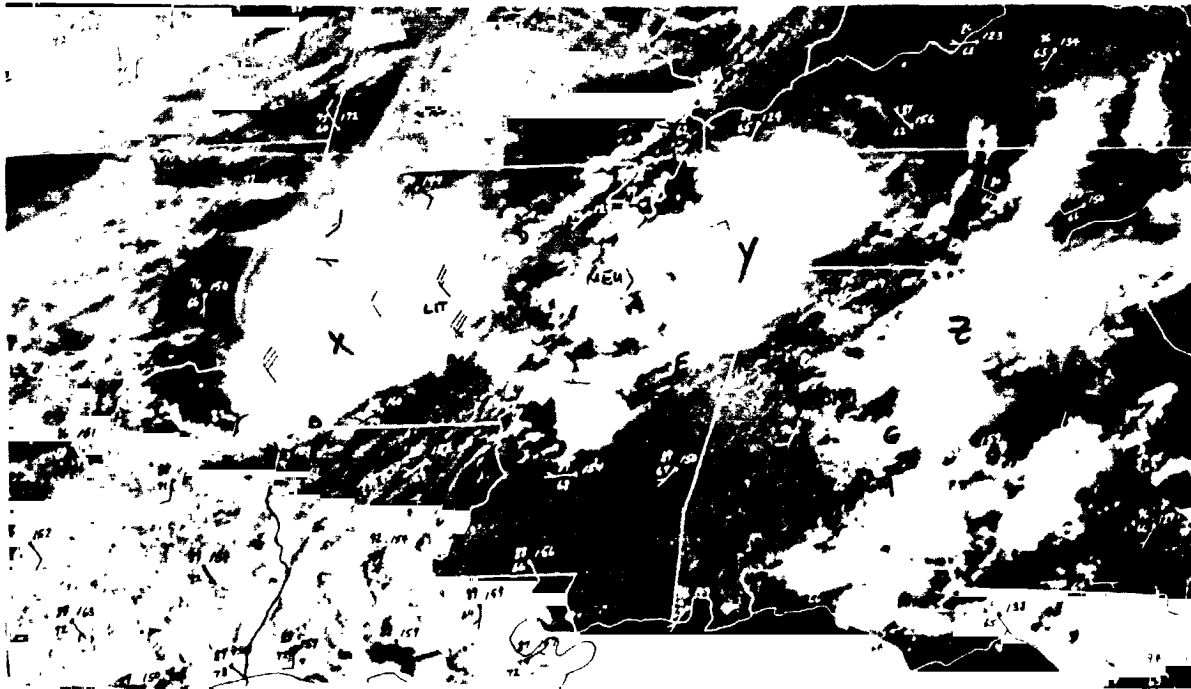
and speed shears produces a rather turbulent environment. Another indicator of significant turbulence is the transverse cloud band. The clouds in areas (B) and (C) are cirrus clouds that are aligned perpendicular or transverse to the direction of the winds at high levels. The avoidance of such areas is a comfort feature to passengers as well as in certain cases a safety feature to passengers who may not be properly restrained for a turbulence encounter. Interpreted satellite images depicting areas of turbulence associated with a jet stream would be useful to an enroute pilot.

SECTION 3 SEVERE WEATHER

Often weather patterns forecasted at the time a flight plan is prepared do not materialize during the flight, or, even more serious, unforecasted severe weather patterns develop during a long flight. This is especially troublesome if the flight is in a remote location and the only advance warning is from the relatively short range of onboard weather radar. A far improved situation would be the near-real time observation of weather along the total flight path of an aircraft throughout the flight. This would allow a pilot to observe severe weather development sufficiently far in advance to prepare and file a revised flight plan that would optimize circumnavigation of the severe weather. On long flights significant economic and passenger comfort benefits may result from flight plan modifications early in the flight in contrast to penetrating the vicinity of the severe weather, observing radar echoes, and feeling one's way through or around the severe weather storm cells.

Another aspect of severe weather that concerns safety is the wind shear environment about thunderstorms. Strong speed and directional shears affect a large area near and ahead of the storm cells. A pilot seeing in the satellite data the approach of severe thunderstorms at his destined airport may wisely back-off on the throttle and thereby allow the weather to pass prior to his arrival.

Figures 3a and 3b show visible data over the southern United States at a time separation of one hour and two minutes. These two visible pictures illustrate the various changes that can be observed in the behavior of convection on an unstable late spring day. At the initial time there are three major convective masses (X, Y, Z). Although the surface winds are generally light southerly throughout the area, one can easily see that convective activity can quickly modify this situation. Note that surface wind directions under the thunderstorm area (X) are generally northwesterly.



a. 2000 GMT, 26 May 1975



b. 2102 GMT, 26 May 1975

Figure 3. SMS-i visible data (0.5 mi. resolution).

The abrupt change in wind direction lies along an arc (A-B-C) that is the boundary of rain-cooled air advancing out ahead of the thunderstorm area. This arc can also be instrumental in setting off new convection in previously clear areas as well as creating severe weather cells where it might intersect another arc, squall line, or frontal zone. Such an intersection of smaller thunderstorm clusters occurred at Memphis (MEM), resulting in a change from a southeasterly wind at 10 knots at 2000 GMT to a westerly wind at 55 knots at 2100 GMT.

A number of changes in general convection can be seen along the squall line stretching from southern Illinois into Arkansas (D-E), and in northeastern Mississippi (F) and eastern Alabama (G). Analysts using conventional data together with the satellite pictures can assess the most probable areas of intensification as well as dissipation due primarily to the high density of observations allowed by the satellite data. Identification in essentially real time of areas of impending changes in the wind direction and the arrival time of these changes are expected to be a possibility in the near future.

SECTION 4

BACK-UP FOR WEATHER RADAR

Weather radar is perhaps one of the best safety features onboard an aircraft. On occasion, however, the quality of radar reception is poor or the radar may even fail completely. If this occurs on a long flight and severe weather encounters are likely, a dangerous condition exists. Satellite images would be a most beneficial back-up capability for such a situation. IR observations of cloud temperatures can easily pinpoint the location of the highest thunderstorm cells by the extremely cold temperatures they exhibit. Also, with high-speed aircraft and a maximum weather radar range of 200-300 miles, warning of weather development is limited. Satellite images would also be useful in providing a long-range weather monitoring and observational capability.

SECTION 5

SUPERSONIC TRANSPORT

Operational introduction of supersonic commercial aircraft creates a need for severe weather data far in advance of what can be seen with today's weather radar limitation of 200-300 miles. At Mach 2, a weather radar can provide, at most, a ten-minute look-ahead. This, in conjunction with the deterioration in radar performance that occurs at higher altitudes, results in an inadequate weather observational system. Here again, near-real time satellite images would be most useful in assessing the weather pattern development at 500, 1000, or even 2000 miles ahead. Should a moderate sized commercial fleet of SST's occupy the airways in the future, a near-real time satellite image capability could be the primary onboard meteorological monitoring system.

SECTION 6

FUTURE SATELLITE CAPABILITIES

Planned for the coming decade are launches of additional geostationary satellites that will provide added meteorological data about the earth's atmosphere. The Severe Storm Observational Satellite Program (SSOS) is being designed to provide high resolution very near-real time observations of severe local storms. Vertical temperature and moisture profiles will be available in addition to winds (obtained from cloud motion) and rapidly updated observations of the changing structure of thunderstorm tops. Beyond the severe storms program, a Synchronous Earth Observatory Satellite (SEOS) Program is being planned that will improve upon the quality and resolution of SSOS data and, in addition, may provide microwave sounding and imaging capabilities. The instrumentation of SSOS has not yet been finalized so that the precise capabilities are unknown. Nevertheless, it is apparent that with SSOS, improved capabilities will be available that may assist in understanding and observing meteorological phenomena that affect aviation such as fog formation and dissipation, exact cloud height, and upper air temperature and moisture profiles.

The potential onboard applications of some of these parameters to a flight crew embarking on a long-distance, high-speed flight to a remote area of the world are discussed below.

6.1 VERTICAL TEMPERATURE PROFILES

The availability of vertical temperature profiles over a wide geographic area has great impact on aviation. The temperature profile that an aircraft experiences during flight largely determines the performance of the aircraft and thereby contributes to the amount of fuel required for the flight. For the supersonic transport, temperature is an even more critical factor.

Satellite vertical temperature profiles are presently available from some polar orbiting satellites but have not yet been incorporated into geostationary satellites. Future geostationary satellite programs such as SSOS and SEOS will provide the capability for vertical temperature profiles with improved resolution and coverage over the presently available profiles. Even these profiles, however, will not have the resolution in the vertical needed to supersede today's balloon-borne system for obtaining temperature measurement at each flight level. Nevertheless, satellite profiles will have an impact on providing temperature measurements at selected levels over many remote locations. These data can then be used to modify conventional upper air charts. Improved upper air charts would be especially valuable to international and corporate airlines using lightly traveled routes. It is conceivable that a relatively modest real-time computation unit tuned to the aircraft flight path and satellite data could produce optimum flight path directions based on temperature and anticipated in-flight wind conditions.

6.2 JET STREAM IN CLEAR AIR

The location of the jet stream in clear air is not well known over the oceans or over remote land areas where aircraft and rawinsonde observations are sparse. A technique has been developed by Broderick¹ to determine the jet stream location in clear air from satellite radiance measurements. These radiance measurements can also be used to derive a vertical temperature profile. Using data from a polar-orbiting satellite over a six-hour period, Broderick estimated the location of the jet axis to within 100 km of its true location at 87% of the points of comparison. Also, in many cases the magnitude of the wind near the maximum wind axis could be estimated. The technique appears most accurate for estimating location of the polar jet, rather than the subtropical, because of its thermally driven nature.

¹H. J. Broderick, "The Relationship Between Vertical Sounder Radiances and Mid-Latitude 300-mb Flow Patterns." Proceedings of Symposium on Meteorological Observations from Space: Their Contribution to the First GARP Global Experiment, COSPAR, Philadelphia, Pa., June 1976.

Future geostationary satellites with vertical temperature sounding instrumentation will be capable of providing near simultaneous radiance measurements over any cloud-free region within its field of view at specified time intervals. Thus, it appears probable that near-real time observations of the polar jet can be made in clear air. Utilization of jet stream information, as previously discussed, is important to aviation from an economic standpoint. Corporate charter and commercial airlines could use this information for flight planning purposes as well as for in-flight modification of existing flight plans.

6.3 FOG

Fog is another problem for commercial aircraft that may be improved by the availability of near-real time high resolution satellite imagery. The formation, lifting, and dissipation of fog at airports is an important problem from the standpoint of safety and economy. Even a fifteen-minute advance notice of fog formation, advection or dissipation in the terminal area would be valuable to aviation. Future meteorological satellites may well have the capability of detail needed to observe and extrapolate high frequency change in fog conditions and thereby evaluate enroute their chances of landing at an airport before it goes below minimums. This would be especially useful at airports where advance terminal forecasts are not available for the anticipated arrival time or in locations where alternate airports are a great distance from the designated airport.

6.4 ADVANCED INTERPRETATION OF SATELLITE IMAGERY

Finally, not to be overlooked is the availability of new weather interpretation techniques useful to aviation that will probably result from the meteorological satellites of the future. For example, a large number of satellite-derived vertical temperature profiles, concentrated over a given geographic region, may be sufficient to determine temperature gradients and accompanying clear air turbulence. An immense benefit to aviation would result from such a

technique. Correlation studies between turbulence observed by aircraft and satellite measurements of clouds, winds, temperature and moisture profiles could lead to an operational technique for mapping turbulence regions in near-real time. Potential also exists for interpretation of satellite data that results in a further understanding of the fog formation and dissipation process. Experience gained from onboard utilization of satellite images together with pilot observations, both meteorological and operational, will undoubtedly provide additional benefits to aviation beyond those discussed above.

SECTION 7
SUMMARY AND CONCLUSIONS

Present utilization of SMS/GOES images by the aviation industry is minimal. From a study of observations presently available from satellites and those observations that will be made by advanced meteorological satellites in the coming decade, it appears that commercial aviation will have ample use for them. These satellite data will, no doubt, be utilized at the Federal Aviation Administration Air Traffic Control Facility, airline meteorological offices and by pilots onboard aircraft. Facsimile transmission of high quality/high resolution satellite images to in-flight aircraft hold considerable promise, especially for aircraft flying remote routes. Charter, corporate, and supersonic transports could justify the utilization of satellite imagery from a cost and safety viewpoint if a low-cost facsimile recording system can be placed onboard aircraft.

The strong potential that exists for near-real time satellite images onboard aircraft appears to justify a feasibility test program of facsimile transmission to aircraft. Appendix A outlines such a proposed program, Satellite Aircraft Flight Environment System (SAFES) involving Continental Airlines. In addition to the objectives of the SAFES program outlined in Appendix A, other results may be achieved. One extremely important result could be the recommendation of future satellite data collection and observation programs that would be tailored to the needs of aviation. Another outcome of the SAFES program could address itself to the future dissemination network for facsimile data. Today satellite facsimile is most often received by telephone line link with a NOAA/NESS facsimile circuit. An Automatic Picture Transmission Station (APT) can also be used to receive weather facsimile (WEFAX) data transmitted by NOAA/NESS via a satellite communication link. The aviation industry, by establishing feasibility and utilization of satellite facsimile data at this time can play a guiding role in designing a satellite data dissemination network that will address itself to the needs of aviation. A description of the type of facsimile transmission system that may be needed in the future is presented in Appendix B.

APPENDIX A

TEST PROGRAM FOR TRANSMISSION OF FACSIMILE TO AIRCRAFT

The proposed first phase of the Satellite Aircraft Flight Environment System (SAFES) program consists of the following. Satellite images obtained from GOES/East and GOES/West will be received each 30 minutes at the meteorology office of Continental Airlines (CAL) via telephone line from NOAA/NESS. These images will be interpreted by a CAL meteorologist and enhanced and transmitted within a very few minutes via Aeronautical Radio, Inc., (ARINC) to a DC-10 aircraft either on the Los Angeles-Honolulu route or the Miami-Los Angeles route. When using the Miami-Los Angeles route, facsimile transmission will be made using VHF frequencies. With the Pacific route, HF frequencies will be utilized. Further technical details of the SAFES program are contained in "Satellite Images to Aircraft In Flight".* The objectives of the first phase of the SAFES program are as follows.

1. To evaluate the technical feasibility of facsimile transmission to enroute aircraft using HF and VHF frequencies. Items to be considered in this evaluation are the quality of image that can be received onboard, the transmission times needed for completing a facsimile transmission, how this transmission time can be minimized, the types of facsimile transmitters and recorders available, the quality, size, weight, cost, and space occupied by various facsimile recorders, the optimum HF and VHF frequencies as a function of range, weather and ionospheric conditions, the ability of facsimile recorders to withstand the take-off, landing and enroute shock, and others.

* Dennis Camp, James K. Luers, and Paul Kadlec. "Satellite Images to Aircraft In Flight", Proceedings of the Seventh Conference on Aero-Space and Aeronautical Meteorology and Symposium on Remote Sensing from Satellites, November 16-19, 1976, Melbourne, Florida.

2. Utility of the presently available satellite images for aviation can also be evaluated. The evaluation will be based upon safety, fuel economy, passenger comfort, and improved operations. Discussion with pilots, airline meteorologists, and operations personnel will be used to establish the value of satellite images under different types of weather patterns. Some of the types of weather situations that will be studied are: severe weather areas, thunderstorms, squall lines, tropical storms, hurricanes, fog areas, jet stream patterns, and turbulence associated with the jet stream. Projection will also be made relative to the value of satellite images onboard aircraft when other meteorological parameters, scheduled for future meteorological satellites are available.

3. In addition to transmission of satellite facsimile data, the SAFES program will also evaluate the transmission of other facsimile data such as weather maps, upper air charts, etc. Transmission of weather maps will be intended to evaluate the potential for self-briefing of pilots in remote sections of the globe.

If the first phase of the SAFES program provides satisfactory results, a recommendation will be made to proceed into a second phase -- transmission of facsimile data via a communication satellite such as ATS or Aerosat. The second phase would evaluate the potential of facsimile transmission to remote sections of the globe.

APPENDIX B

WORLDWIDE DISSEMINATION OF SATELLITE DATA TO VARIOUS USERS

Meteorological data from geostationary satellites have applications to many groups of people now, and will have even more users in the future when advanced satellites provide additional and improved data. Of primary concern from a communications standpoint is how to get the large volume of available data to each of the users and analyzed and interpreted so that it will satisfy their needs, and how to provide this information in near-real time. Satellite observations will be made of weather conditions, ocean currents, surface conditions such as ice formation, volcanoes, dust storms, and a host of other events. Users of such data will include weather forecasters, aviation personnel, fishing fleets, the shipping industry, disaster alert centers, farmers, foreign governments, conservationists, environmentalists and others. A distribution system for these data may consist of transmission of facsimile data sets on a worldwide basis to specified users via communication satellites. For example, all ocean and weather information of interest to the fishing fleet could be transmitted on a selected frequency from ground station to a communication satellite for relay to all corners of the globe. To receive this information, a ship with the proper antenna, receiver and facsimile recorder would tune its receiver to the proper frequency and record the desired information. Tuning to different frequencies would allow acquisition of data designed for other groups of users such as the aviation industry. The following paragraphs discuss a type of meteorological dissemination network that would be beneficial to the aviation industry.

Worldwide dissemination of satellite data would be feasible after all SMS/GOES geostationary satellites are in orbit and all data are being received by a central processing facility such as NOAA/NESS. The data from each SMS satellite encircling the globe would be transmitted to NOAA/NESS immediately as it is received at the various ground stations.

The data would be processed and sectorized between 60° North and 60° South latitude. Sectorization of data would be made by a latitude/longitude grid. An image of a sector would be identified by the latitude and longitude of the midpoint of the sector and the image resolution.

Visual and infrared images of each sector would be interpreted for meteorological content by a satellite meteorologist. Observations made by the meteorologist would be affixed to the image either by directly marking or typing on the image or by a written description typed on the margin of the picture. For example, observations of cloud temperatures, cloud height, and wind direction could be directly noted at those locations on the image. Discussion type information such as the anticipated intensification of a thunderstorm would be attached to the margin of the image. Accompanying the interpreted satellite image of a sector would be other weather information for that sector, such as vertical temperature profiles, vertical moisture content profiles, anticipated areas where icing conditions exist for aircraft, precipitation presently occurring throughout the sector, surface conditions, temperatures, snow cover, or whatever other information may be available for that sector and useful for aviation interests. The satellite images with the accompanying charts and graphs, for a sector, would be transmitted from NOAA/NESS to a communications satellite for relay to that section of the globe for which the sector pertains. For example, Figure 1 shows the transmission of all sectors from Region A via a communication satellite to the Region B which contains A. The transmission of data for each sector in Region A would be on a scheduled basis with a thirty-minute sequencing time. Data for each sector would be updated at its next transmission time -- thirty minutes later. It is anticipated that a facsimile transmission for a sector could be made in a time frame of one minute. Reception of the satellite imagery and other data would be available to any aircraft (or ground station) with the proper antennas and receivers. The choice of the transmitting frequency bandwidth, etc., would be influenced by the users of such a system and could be chosen in conformity with constraints of the Aerosat Program.

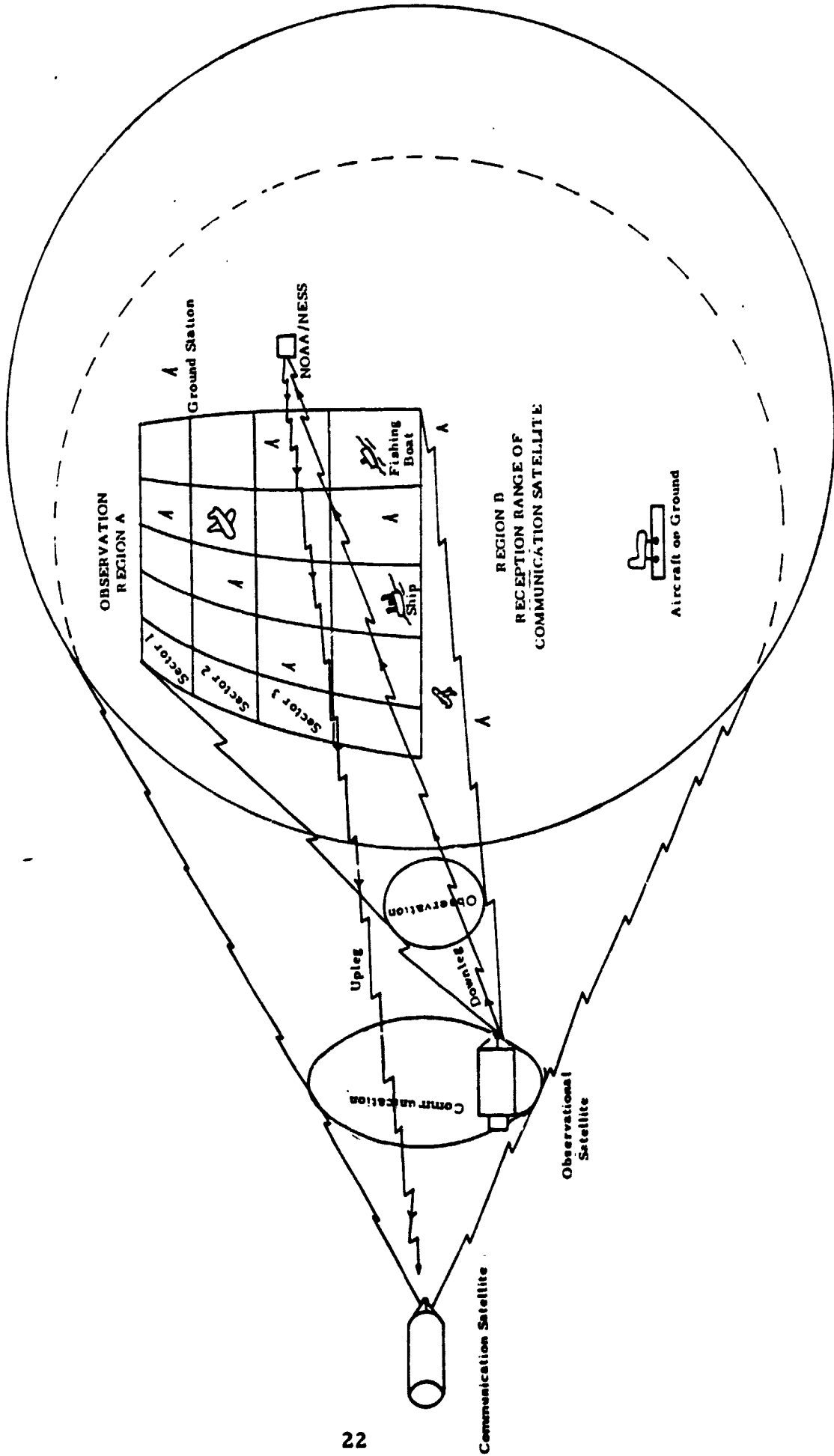


Figure 1. Satellite Observation and Communication Network

UTILIZATION OF DATA

Satellite imagery would be received each half hour by an aircraft, ground station, etc., within range of the transmission satellite. For a wide-body aircraft to receive the facsimile transmission, all that would be required would be a satellite antenna (already available on many wide-body aircraft), receiver (already onboard), and a facsimile recorder. By tuning to the facsimile transmission channel at the proper time during the half-hour transmission sequence, a pilot would receive satellite images and other weather data for his sector of interest. In addition to the uses of satellite images discussed, a world-wide dissemination network would provide a self-briefing capability to a pilot anywhere in the world, either while on the ground or in flight. All weather information needed by a pilot to make a flight plan would be available and up to date anywhere in the world.

Charter, cargo, and corporate aircraft equipped with satellite reception capability would also receive satellite images, weather charts, upper air temperatures and wind charts, etc., in the air or on the ground, essentially anywhere in the world. This would be especially attractive for flights where accurate, up-to-date weather information is sparse. Presently, much of the real time and interpretive data is not available to cargo and corporate pilots, since they have no meteorologist. It would also alleviate the need for renting expensive telephone facsimile-carrying circuits.

Worldwide reception of satellite data at ground stations has many aircraft applications. In foreign countries and especially underdeveloped nations, up-to-the-minute satellite images could provide useful weather observations for various aviation planning usage. Potential users could include the Flight Service Stations, the local television stations, consulting meteorologists, corporate aircraft owners, remote landing sites, etc.

Although the above systems concept is clearly five to fifteen years in the future, an initial facsimile transmission and utilization program is necessary to establish an experience base from which a worldwide dissemination program for satellite data can be developed in an orderly manner. The feasibility study described in Appendix A would fulfill this need.