SURVEY: NATIONAL METEOROLOGICAL CENTER

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SURVEY: NATIONAL METEOROLOGICAL CENTER

Prepared For

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MARSHALL SPACE FLIGHT CENTER
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INTRODUCTION

The National Meteorological Center (NMC) is an element of the National Weather Service (NWS), which belongs to the National Oceanic and Atmospheric Administration (NOAA), under the Department of Commerce. The hiearchical relationship of the NMC to its parent organizations and its internal divisions and branches that are of interest to this report is presented in Figure 1. The NMC is comprised of three operational divisions (Development, Automation, and Forecast) and an Administrative Division as illustrated in Figure 1.

The names of the three operational divisions within the NMC describe their job functions fairly well. The Development Division develops and implements mathematical models for forecasting the weather. The Automation Division provides the software and processing services to accommodate the models used in daily forecasts. The Forecasting Division applies a combination of numerical and manual techniques to produce analyses and prognoses up to 120 hr into the future, emphasizing the period 2 to 72 hr. This guidance material is combined with severe storm information from the National Hurricane Center (NHC) and the National Severe Storms Forecasting Center (NSSFC) to develop locally tailored forecasts by the Weather Service Forecast Offices (WSFOs) and, in turn, by the local Weather Service Offices (WSOs). Figure 2 shows a very general flow of this information. A more detailed illustration of data flow into, within, and from the NMC is given in Figure 3. Figure 4 depicts the interrelations between the various meteorological organizations and activities, of which the NMC is more or less the focal point, especially for non-DoD weather activities.

The operations of NMC will be modified somewhat when the NWS Automated Field Operations and Services (AFOS) System becomes operational in 1981. NMC will be the entry point for all basic national analysis, prognostic, and guidance products. It will also be the exchange point for most international data and, during the early stages of implementation, for the exchange of data and products between AFOS and the parts

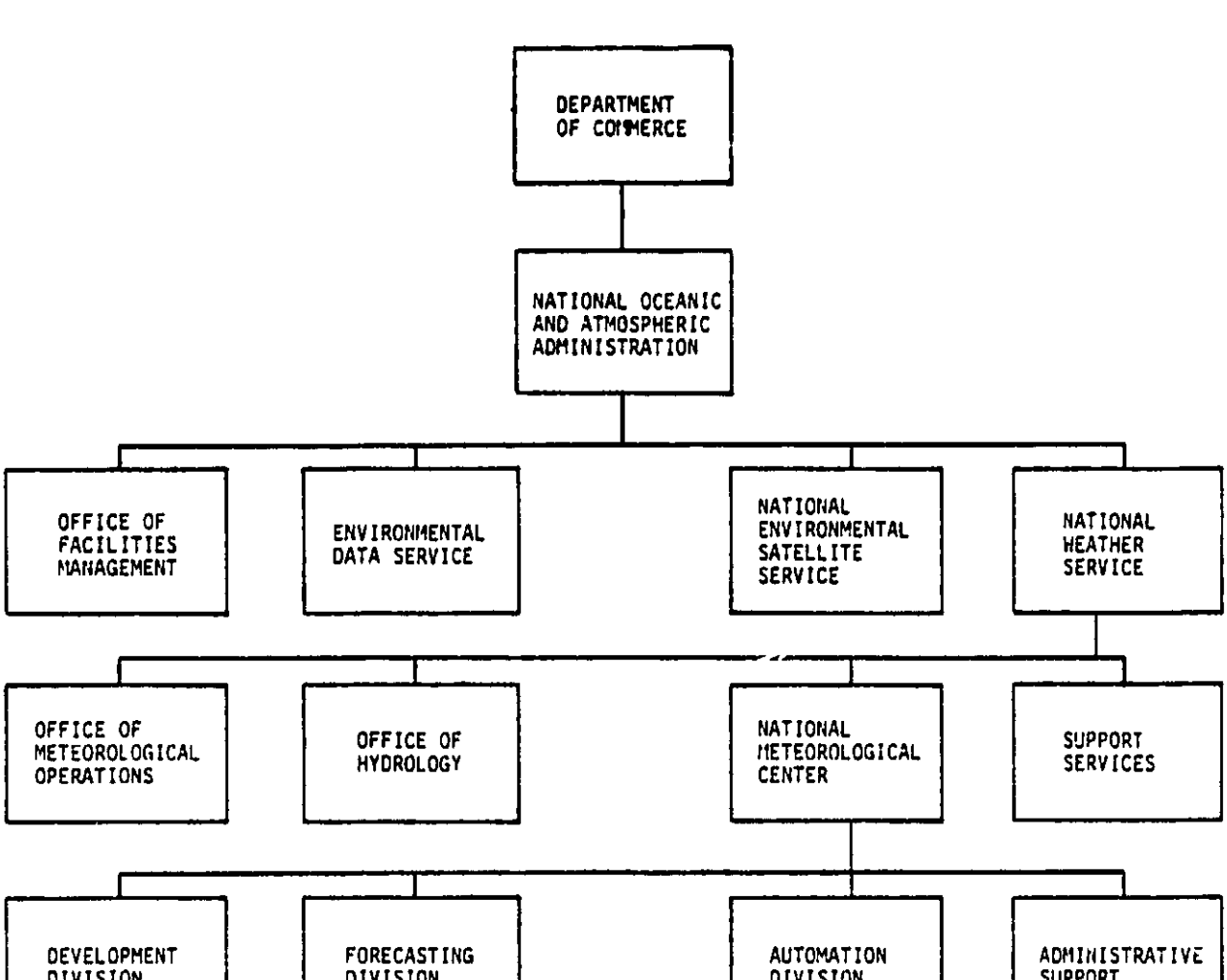

FIGURE 1. NOAA ORGANIZATIONAL STRUCTURE

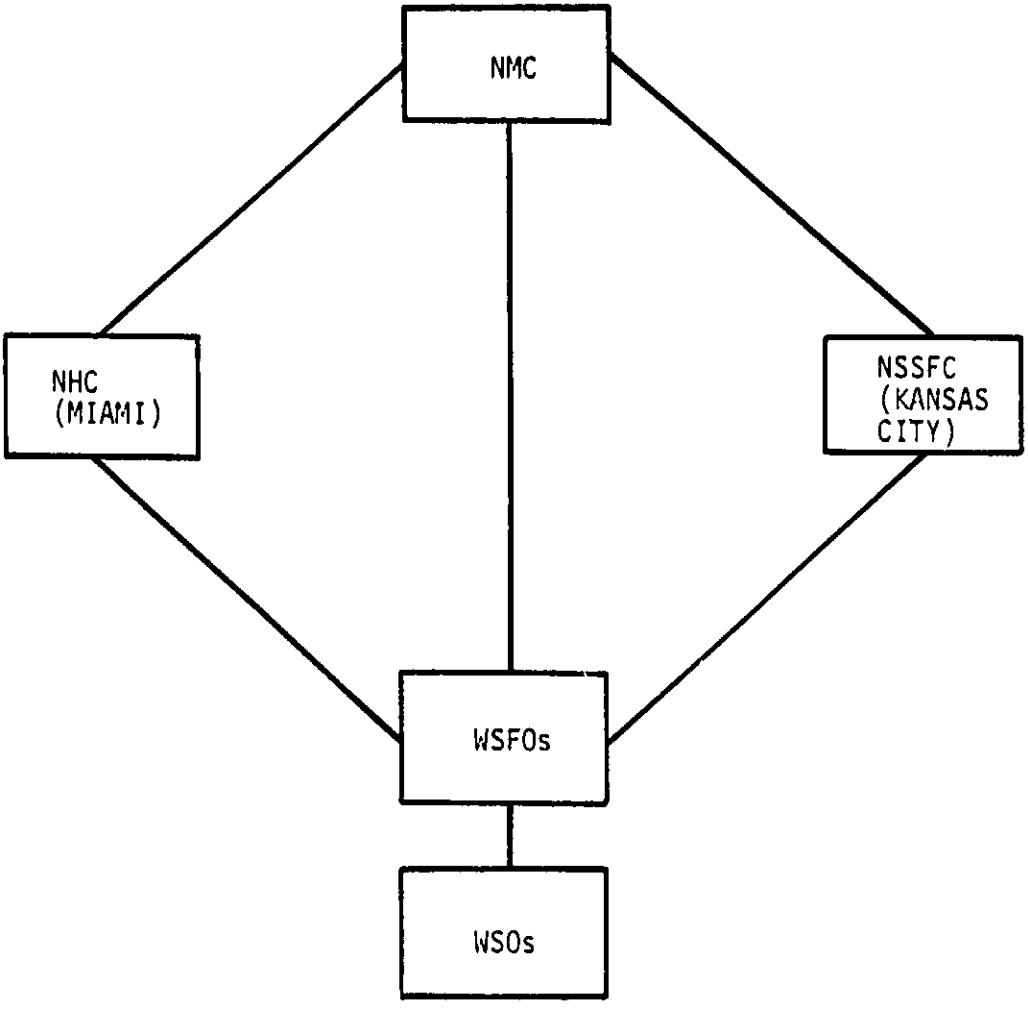

FIGURE 2. NMC FORECAST/WARNING INFORMATION DISTRIBUTION

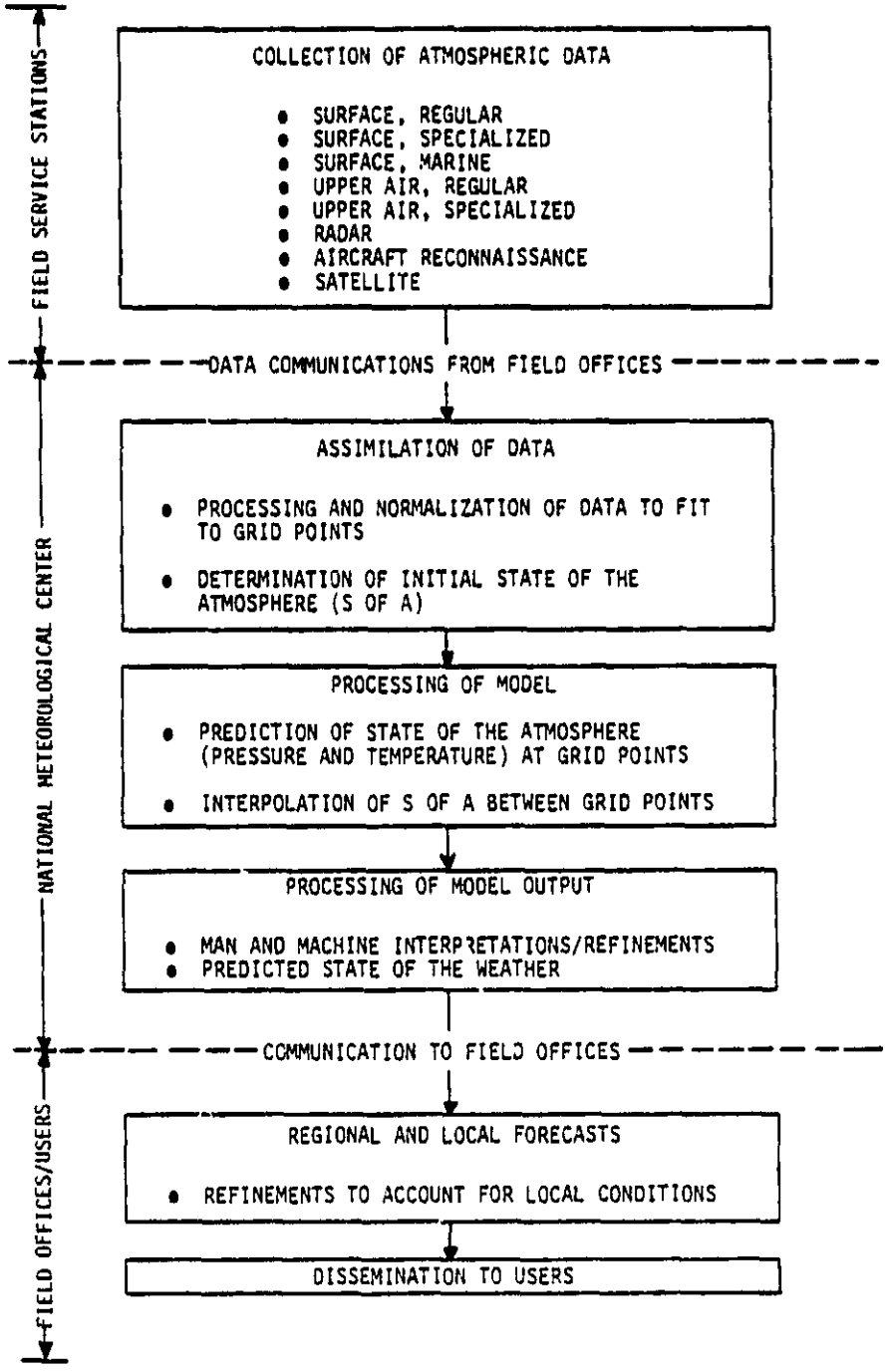

FIGURE 3. DETAILED FLOW OF METEOROLOGICAL INFORMATION

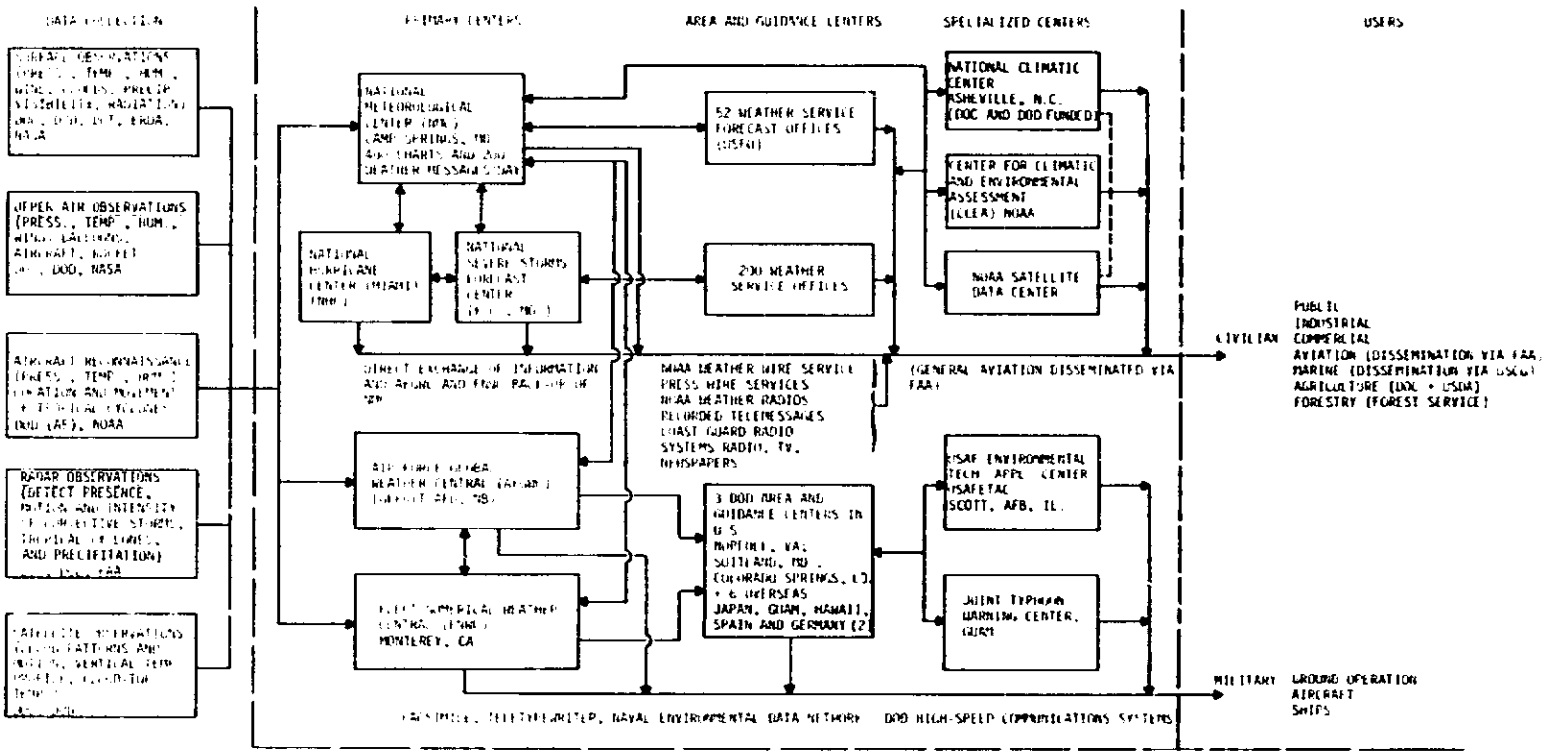

FIGURE 4. INTERRELATIONSHIPS BETWEEN METEOROLOGICAL CENTERS FOR ANALYSIS AND OPERATIONAL FORECASTING

of the NWS system not yet implemented. The Air Force Global Weather Central (AFGWC) supports the NMC as a backup facility should NMC be unable to provide meteorological products for any reason.

FORECAST MODELS WITHIN NMC

The Development Division of NMC develops mathematical models to be used in forecasting weather based on observational data from surface, upper air, aircraft reconnaissance, radar, and satellite observations. These models are implemented by the Automation Division on the three IBM 360 Model 195 computers at the NOAA Central Computer Facility, which is located in FOB#4 in Suitland, Maryland.

The primary models used include the hemispheric six-layer baroclinic model, which uses the primitive equations (PE) on a 380- by 380-km grid, the Limited-Area Fine-Mesh (LFM) model, which uses the primitive equations on a 190- by 190-km grid, and Model Output Statistics (MOS). Other models are the Hemispheric Fine-Mesh Model (HFM), the Nested Grid Model (NGM), and the Nine-Layer Global Prediction Model.

Since 1966, the PE model has been the principal NMC operational model. The LFM model has been used to improve the output provided by the PE since 1971. The LFM provided forecasts to 24 hr until early 1976, when the program was expanded to run to 48 hr. The forecasting community in the United States now receives forecasts out to 48 hr from the PE and regional LFM models twice each day, based on analyses made from 0000 and 1200 GMT surface observations. The PE model is also run out to 84 hr, once per day, from the 0000 GMT observations.

The PE and LFM models are numerical prediction models that provide the state of the atmosphere. Objective forecasts of local weather are obtained using model output statistic techniques to complement these numerical prediction models. Using this technique, local observations of weather parameters are matched with output parameters from numerical models for a period of a year or more. Statistical techniques then are

used to derive forecast equations that can account for biases and inaccuracies in the numerical model and for local climatology. MOS predictions giving probability of precipitation, conditional probability of frozen precipitation, minimum and maximum surface temperatures, surface wind direction and speed, ceiling, and visibility are transmitted twice daily over nationwide facsimile and teletypewriter. During the warm season, MOS forecasts of the probability of thunderstorms and the conditional probability of severe local storms are made available to forecasters in both digital and map form once per day.

The use of wind and temperature predictions from NMC's PE model has become routine among domestic and foreign airlines for flight planning. Direct output of forecast parameters at cities in this country (e.g., boundary-layer winds, layer humidities, vertical velocity, and lifted index) from the LFM in bulletin form are available twice each day via request-reply from the Federal Aviation Administration's Weather Message Switching Center in Kansas City, Missouri. These parameters are also very useful to the forecaster in the prediction of precipitation. The MOS technique has been applied to forecasts of many weather elements including temperature, precipitation, winds, and thunderstorms and is now an important part of the daily operational products transmitted via fasimile and teletypewriter by NMC.

It is difficult to specify progress in the state of the art in numerical forecasting of rainfall occurrence and quantity, thunderstorms, clouds, visibility, and ceiling since most numerical forecasts of these weather elements have become available only within the last 2 or 3 years. Useful forecasts of minimum and maximum temperatures at individual cities, however, have been available to forecasters from NMC's computer facility for several years. During the period between 1968 and 1975, a steady increase in forecasting skill can be attributed to several factors, including rederivation of the equations with a layer data base, increased skill of the PE model to make the forecasts, and introduction of the MOS technique in 1973.

Temperature is, according to most weather forecasters, one of the easiest weather elements to predict; precipitation is one of the most difficult. Numerical forecasts of precipitation have been the least useful of all the output from numerical models. According to Fawcett*, personal skill and previous experience in interpretation of numerical guidance are needed by forecasters when making precipitation forecasts. Another factor that shows as a seasonal improvement in forecasting is that it is easier to predict occurrence and distribution of precipitation in winter storms than for summer thunderstorms.

*E. B. Fawcett, Current Capabilities in Prediction of the National Weather Service National Meteorological Center, Bulletin American Meteorological Society, pp. 143-149, February 1977

1. DATA GENERATOR ELEMENTS

Not applicable

2. SPACE DATA PROCESSING ELEMENTS

Not applicable

3. SPACE DATA STORAGE ELEMENTS

Not applicable

4. SPACE DATA HANDLING ELEMENTS

Not applicable

5. SPACE-TO-GROUND COMMUNICATION ELEMENTS

Not applicable

6. PREPROCESSING ELEMENTS

Not applicable

7. PROCESSING ELEMENTS

The processing elements presented in this section are those that exist at the NOAA facility located in Suitland, Maryland.

7.1 NMC PROCESSING ELEMENTS

Three IBM 360/195 computers connected by computer-to-computer (CTC) interface are the primary components of the NOAA Central Computer Facility. These systems are used to process observational data from throughout the world and to run large-scale modeling programs on this data to produce forecast guidance output in the form of alphanumeric text and charts. Figure 7-1 depicts the general hardware configuration of the data processing facility, and Figure 7-2 shows the normal software configuration of the IBM 360/195 complex.

7.1.1 NMC Data Input

In the course of a day, the NMC receives the following observations from points around the world:

- 14,000 synoptic and 25,000 hourly surface and aviation reports
- 2,500 synoptic ship reports
- 2,500 atmospheric soundings
- 3,500 aircraft reports
- All available weather satellite data concerning cloud patterns and motion, vertical temperature profiles, and cloud-top temperature
- Aircraft reconnaissance reports of location and movement of tropical storms as needed.

7.1.2 NMC Data Products

Scheduled output products from the NMC are as follows:

- Basic forecasts are issued twice daily at 0Z (7 PM EST) and 12Z (7 AM EST).

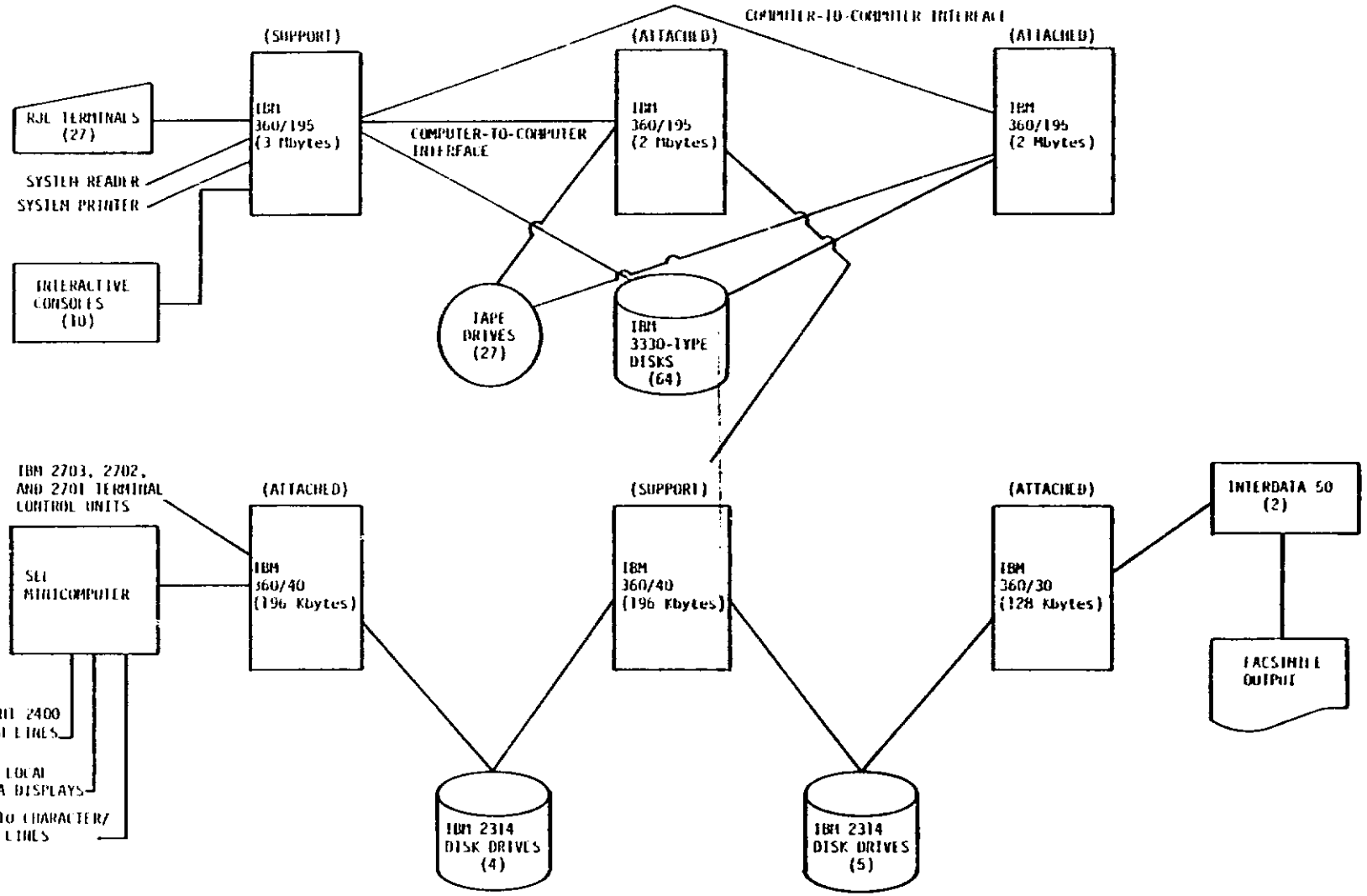

FIGURE 7-1. GENERAL HARDWARE CONFIGURATION OF NMC DATA PROCESSING FACILITY

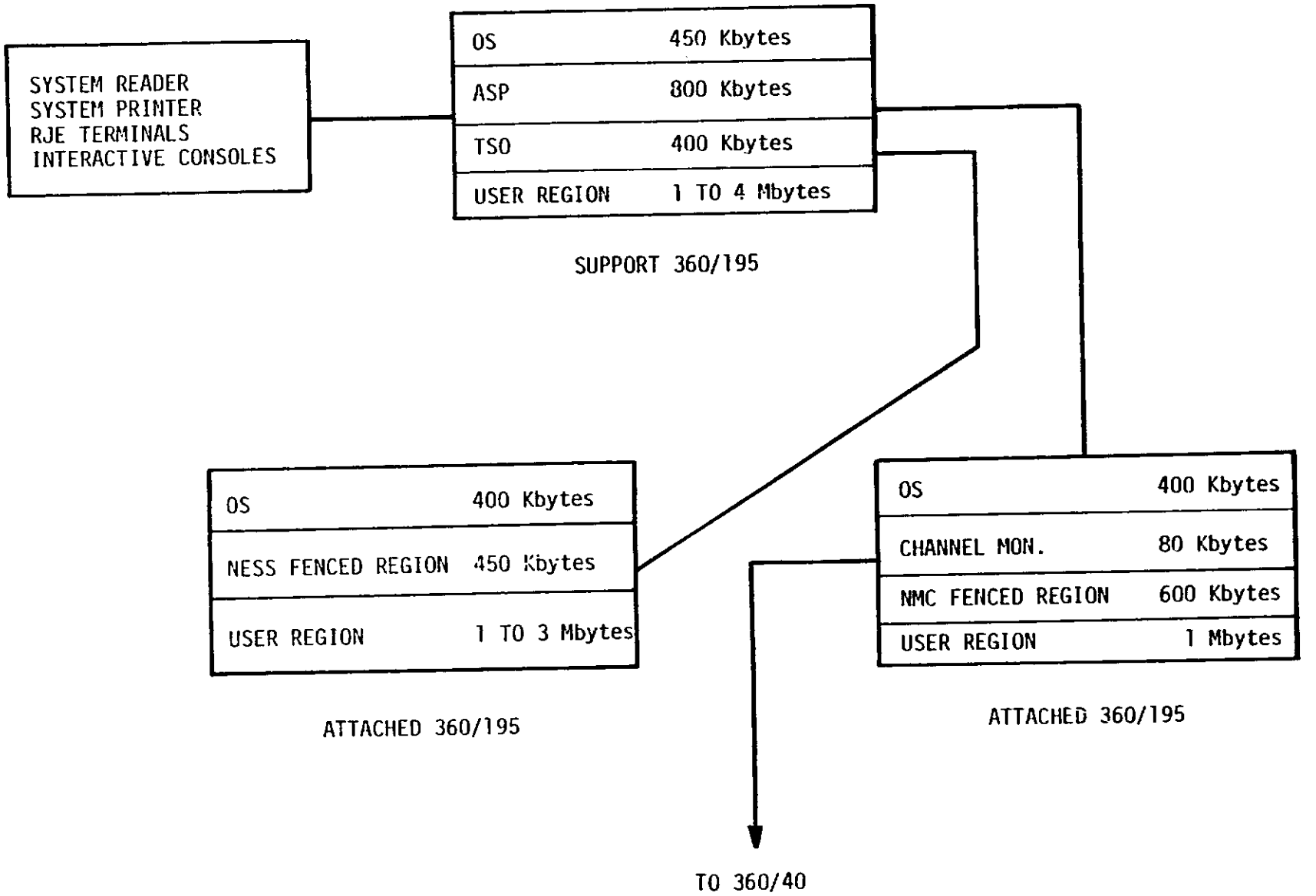

FIGURE 7-2. NORMAL SOFTWARE CONFIGURATION OF THE IBM 360/195 COMPLEX

- A North American Surface Map is produced every 3 hr. A preliminary map containing primarily surface observations is produced at about 20 min after the hour, and a final version containing the remaining surface, aircraft, and synoptic data is produced by about 40 min after the hour.

- A Northern hemisphere chart is produced four times daily.

- Aviation surface charts are produced eight times daily.

- Facsimile products are prepared by NMC and distributed via the Forecast Office Facsimile System (FOFAX), the National and Aviation Meteorological Facsimile Network (NAMFAX), and the National Facsimile Network (NAFAX). Tropical area analyses and prognoses are provided by NMC for use by the National Hurricane Center via the Tropical Regional Analysis Facsimile Circuit (TROPRAN).

- The Intra-Alaska Facsimile Network is used to distribute NMC graphic materials throughout Alaska.

Sample output products are shown in Figure 7-3, which shows a 700 mbar analysis sample, and Figure 7-4, which depicts a portion of the NMC world observation chart.

7.1.3 NOAA Central Computer Facility Hardware

The principal data processing hardware elements within the NOAA Central Computer Facility are:

- Three IBM 360/195 computers (the support system has 3 Mbytes memory and each of the attached systems has 2 Mbytes)

- Two IBM 360/40 computers (each has 196 Kbytes of memory)

- One IBM 360/30 computer (with 128 Kbytes of memory)

- One SEL minicomputer

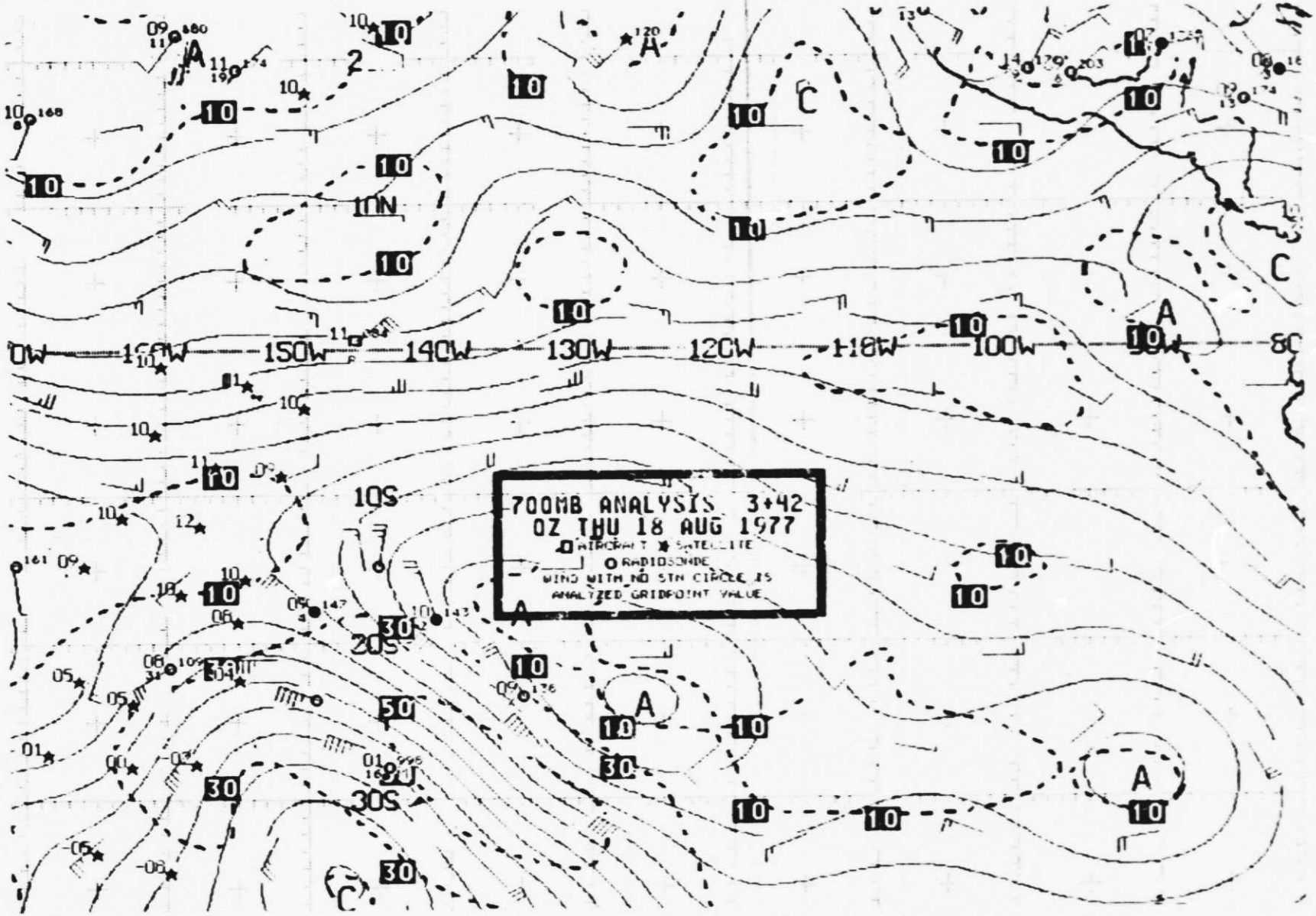

FIGURE 7-3. NMC 700 mbar ANALYSIS SAMPLE

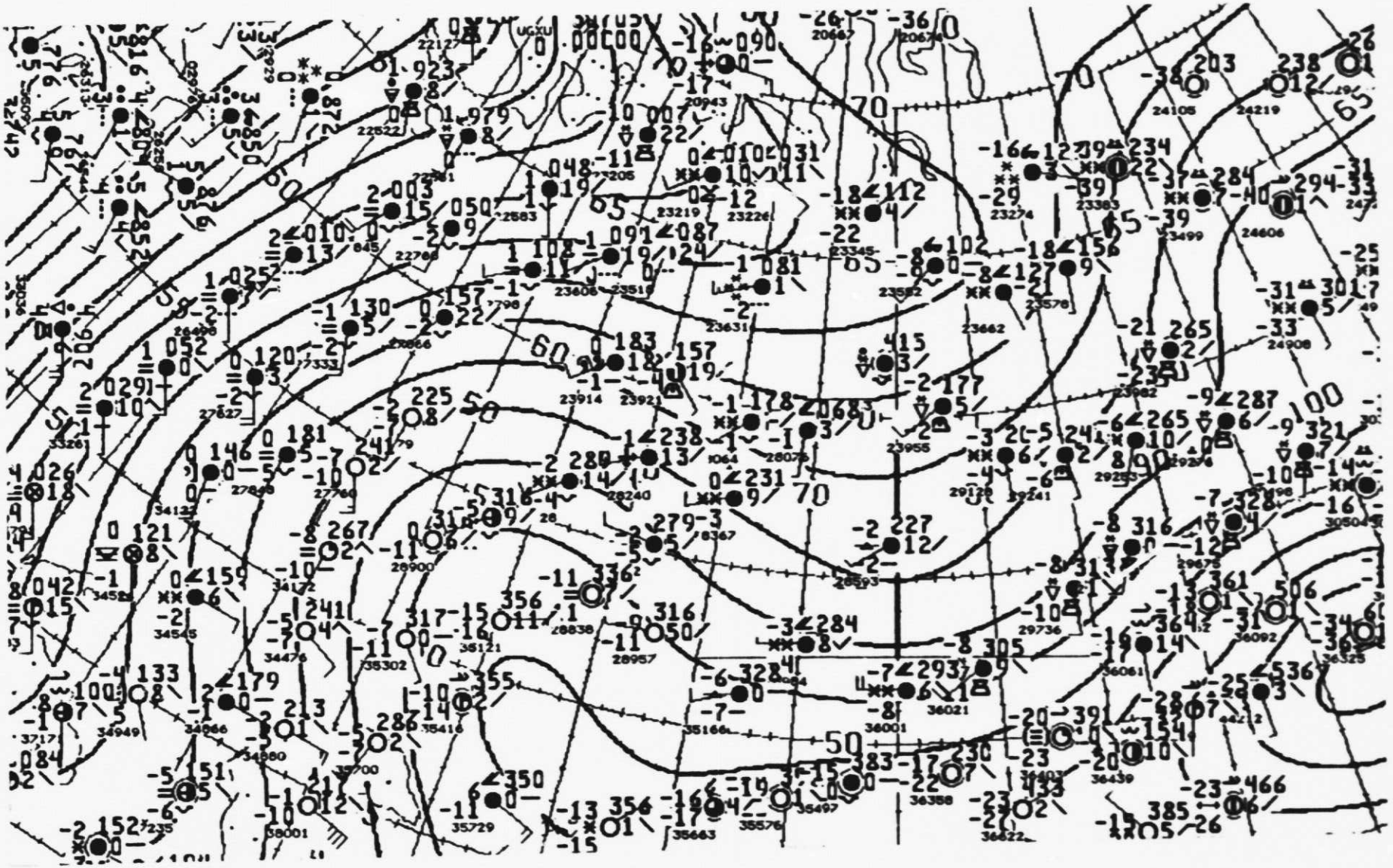

FIGURE 7-4. PORTION OF NMC WORLD OBSERVATION CHART

- Two Interdata 50 minicomputers
- Sixty-four IBM 3330-type disk drives (100-Mbytes capacity each)
- Nine IBM 2314 disk drives
- Twenty-seven tape drives
- Twenty-seven RJE terminals.

In late 1977, the Six Layer Primitive-Equation (6LP) model is planned to be replaced by the Hemispheric Fine-Mesh (HFM) Model. The HFM is basically the same as the 6LP except it uses a half-mesh size. It should be noted that going to this model is expected to increase the workload by a factor of 5. The NWS staff is confident that this added processing load can be accomplished using existing hardware. However, this added processing also can push the existing configuration to the brink of its capabilities and any additional effort will likely require increases in the processing capabilities of the facility. Internal studies have been performed to evaluate the tradeoffs associated with replacing the existing configuration with a CRAY-1 versus adding a fourth IBM 360/195. A decision has not been made, but the indications are that a fourth IBM 360/195 is the probable conclusion that will be reached. Another area under investigation is the possibility of replacing the IBM 360/40's with an IBM-compatible CDC machine. Again, this decision is still pending.

8. DATA BASE SYSTEM ELEMENTS

A data base is maintained of 1,600 North American hourly reporting stations, which are primarily FAA and NWS stations. These data are used by the models and are also accessible by the KCRT and River Forecast Center users via RJE. (Twelve of the 57 Sanders 720 CRTs (2,400 baud, full duplex) are connected to the central facility located in Suitland, Maryland.)

Sequential partitioned data sets are used to save observational data. A file directory is maintained in which the file name consists of the time of data reception and pointers to the actual data. A data set is maintained so that the user may request hourly, latest, or previous data.

The data base handlers use ISAM techniques (random access with index table) basically using their own software. The operating system has also been tailored to fit these requirements.

All observational data are maintained for 7 days, and selected archival data sets are kept on offline disk packs for verification and composite preparation. Data are then put into microfiche and hardcopy form and sent to the National Climatic Center in Asheville, North Carolina, for archival.

9. DATA DISTRIBUTION ELEMENTS

Communications are handled by an IBM 360/30 and two IBM 360/40 computers. The IBM 360/30 is interfaced to two INTERDATA 50 computers by a 50-kbit line. This portion of the system generates all facsimile output products. A front-end Systems Engineering Labs (SEL) minicomputer, which is connected to one of the 360/40's, handles point-to-point communications for the 360/40 systems. This collection and dissemination of meteorological information is accomplished via four 2,400-baud FDX, 43 medium- and low-speed domestic circuits, and three 2,400-baud FDX and 21 low-speed international circuits.

A message switching directory is maintained on disk and is referenced each time a message is received from polling a station in the communications system. Approximately 8,000 uniquely identifiable message descriptors are contained in this directory.

All observational data received are sent to the 360/195 processors for use in forecast and analysis. The path of this data is from the communication system via common disk to the processing system, and from there to the 360/195 by computer-to-computer channel.

Under normal conditions, a complete set of surface data are received within 15 min of the initiation of the polling process (also called "data time"). The synoptic data are received at about 40 min after data time. About 6 hr after data time, all information from ships has been received. Three circuits transmit ship observational data to NMC. The data are then run in the background partition with special programs that perform quality control functions.

Digital graphics products are sent from the 360/195 via computer to computer interface to the support 360/40, stored on a common disk, retrieved, and transmitted to users by the Digital Graphics System (360/30) via the INTERDATA 50 minicomputer in either analog or digital

form. Alphanumeric data from the 360/195 are sent via computer-to-computer interface to the support 360/40 and stored on a common disk, where it is retrieved and transmitted to the appropriate station via the communications system.

Approximately 550 terminal forecasts are distributed at regular time intervals and weather warnings are transmitted as appropriate. These messages are maintained on disk in the message switching directory. All information required for local distribution and external dissemination are available in the descriptor entry.

NMC data products are disseminated throughout the world by the NWS/FAA intercommunications system shown in Figure 9-1. For a more detailed discussion of the communications network refer to a report entitled "Survey: Federal Aviation Administration National Communications Center" and in particular the information concerning the Weather Message Switching Center (WMSC).

As is evident from Figure 9-1, NMC products are distributed internationally. NMC provides the U.S. inputs to the World Weather Watch and provides the most important forecasts for marine weather and for the southern hemisphere. The primary input to these forecasts is satellite data.

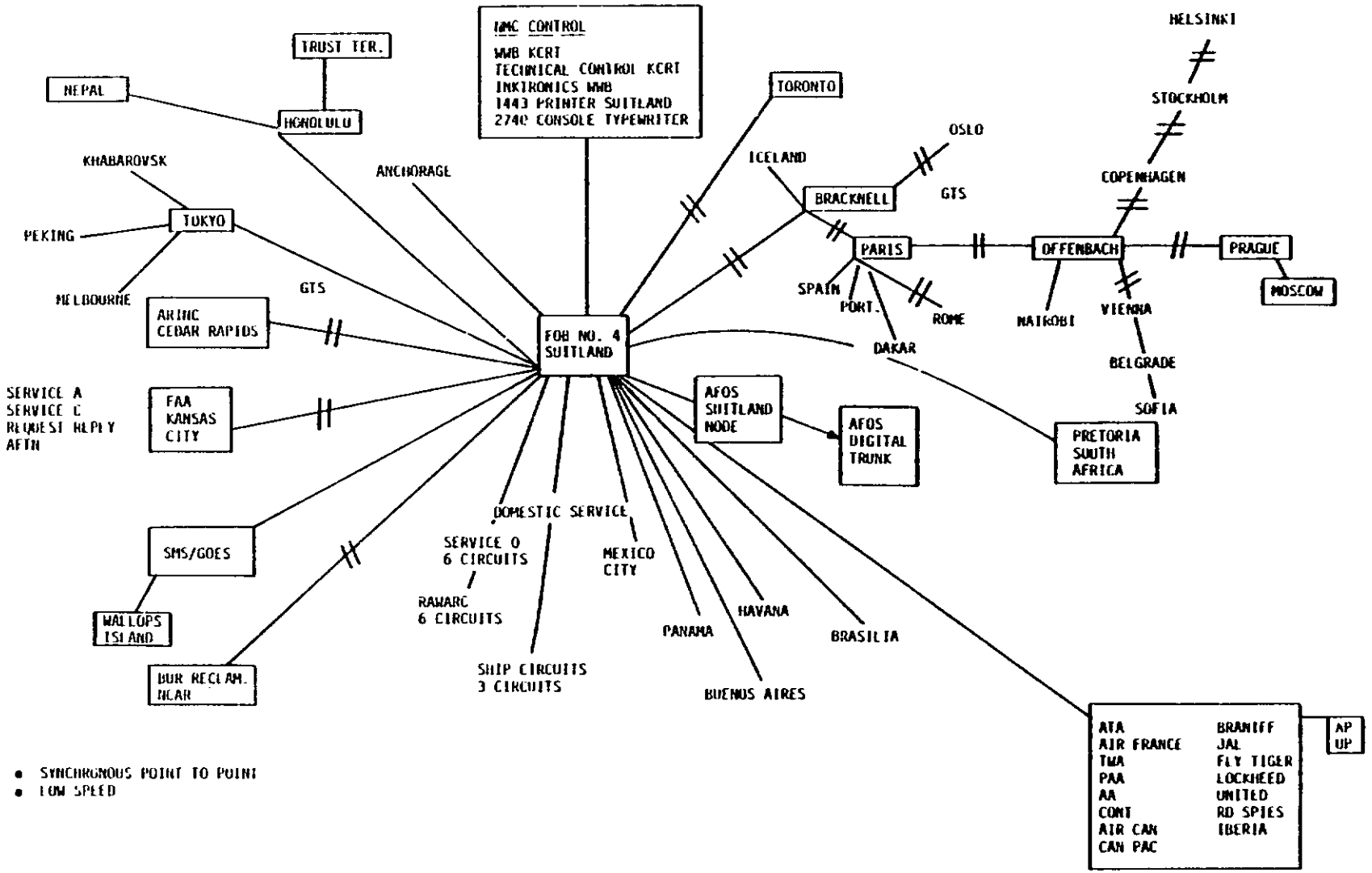

FIGURE 9-1. NMC INTERCOMMUNICATIONS SYSTEM

10. INFORMATION PRESENTATION ELEMENTS

To be determined.

11. WORKLOAD/CAPABILITIES

The NMC and the National Environmental Satellite Service are by far the largest users (approximately 90%) of the data processing resources of the IBM 360/195 computer systems at Suitland. The remainder of users consists of members from the Office of Hydrology, government-supported university research, and other NOAA organizations. Fenced regions are set up especially for NMC and NESS users; the NMC fence consists of 600K and the NESS fence has 450K in the attached 360/195 systems. Other users compete for user regions of 1, 1.3, and 1.4 Mbytes; one user region is located in each 360/195.

Approximately 2,000 modules are executed on the 360/195's each day. About 700 to 800 modules are run within 100 to 200 jobs and approximately 300 modules are used to process hourly data.

Approximately 1 hr is required to complete a 24-hr forecast on the 360/195, which operates at a machine speed of approximately 7.2 MIPS. To this processing time must be added:

- The time necessary to assimilate the data, which remains almost constant regardless of the length of the forecast (about 1 hr on the 360/195)
- The time required for generating the state of the weather forecast at NMC. This is dependent on the difficulty of the weather situation and on the skill of the meteorologist (between 1 and 2 hr)
- The transmission time to the WSFOs (a few minutes).

Current models in use are constrained to the processing capabilities of the 360/195. The future trend will be toward both improving the models and toward reducing the grid size used to make better use of available data. Both will increase the processing time required to produce a forecast substantially. At best, for instance, reducing the

grid size by one-half is expected to increase processing time by a factor of five. When the grid size is reduced in late 1977, it is expected that the increased processing load will essentially take up the available processing reserves within the NMC system. One concern to NMC personnel is that reducing the grid size may be corrupted more by coarseness in processing as a result of roundoff than was originally believed. Studies are currently underway to determine if this problem has been underestimated.

Satellite data will be used more in the future, particularly if the resolution of these data can be improved by a factor of 2. One problem with using satellite data is instrumentation errors; future generation satellites (e.g., TIROS-N) are expected to have largely overcome this problem. Another is the problem of moving cloud contaminations. Satellite soundings are based on a clear atmosphere, so any clouds that are present cause errors. On the other hand, tracking clouds by satellite yields information concerning wind direction and velocity.