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19. Abstract: Report presented to the Twenty-Second Space Congress, Cocoa Beach, Florida, 23-26 April 1985. Describes background of a Joint USAF-NASA project to upgrade forecast inputs at the Cape Canaveral Forecast Facility (CCFF) in support of Space Shuttle and missile launch operations at the Eastern Test Range. Before the start of Shuttle operations, the CCFF had been geared to support missile launches with forecast requirements slanted towards launch pad safety (lightning, high winds, toxic diffusion) and upper air wind shears. Shuttle support added the problems of forecasting safe conditions (visibility, ceilings, crosswinds, precipitation, turbulence) for emergency shuttle landings immediately after a launch attempt, or for a normal landing at the Kennedy Space Center Shuttle Landing Facility. Short range and microscale Shuttle forecast requirements could not be met with the technology in place. To deal with the shortfall, NASA and USAF (Det 11, 2WS) initiated a Meteorological Systems Modernization Program (MSMP), the intent of which is to minimize environmental effects on the Shuttle by providing the most forecast advice possible to support managers during processing, launch, and recovery. Shuttle weather sensitivities are presented, along with the architecture of the forecast support system being assembled to meet these challenges. (Author)

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Status Report on the Upgrade of Weather Forecast Support to Shuttle Operations

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ABSTRACT

The report details the background of a joint USAF and NASA project to upgrade the forecast inputs at the Cape Canaveral Forecast Facility (CCFF) in support of Space Shuttle and missile launch operations at the Eastern Test Range (ETR). Prior to the start of Shuttle Operations, the CCFF had been geared to support missile launches with forecast requirements slanted towards launch pad safety (lightning, high winds, toxic diffusion) and upper air wind shears. Shuttle support added the problems of forecasting safe conditions (visibility, ceilings, crosswinds, precipitation and turbulence) for Shuttle emergency landing immediately following a launch attempt or for normal end of mission landing at the Kennedy Space Center Shuttle Landing Facility. The short range and microscale forecast requirements for Shuttle could not be met with the inplace technology. To deal with this support capability shortfall, NASA and the USAF (Det 11, 2WS and the Eastern Space and Missile Center) initiated a Meteorological Systems Modernization Program (MSMP). The intent of this weather support upgrade is to minimize the impacts of the environment on the Shuttle by providing the most accurate possible forecast advice to support managers during processing, launch, and recovery operations. Shuttle weather sensitivities are presented along with the architecture of the forecast support system being assembled to meet these challenges.

INTRODUCTION

As the Shuttle hardware and operations mature, system turn around time will dramatically decrease and the launch rate will increase to a rate of two launches per month (table 1).

TABLE 1
Projected Shuttle Launches By Year

YEAR	TOTAL LAUNCHES
1985	12
1986	17
1987	23
1988	24

It was evident as early as 1982 that weather and weather support would become more critical elements in maintaining this high operational launch rate. NASA and the USAF, at the local level, formed a joint Meteorological System Modernization Program. This group is co-chaired by Technology Projects Office of Kennedy Space Center (NASA) and Det 11, 2WS of Patrick Air Force Base (USAF). The purpose of this group is to upgrade the inplace forecast technology to ensure the challenge of Shuttle weather support can be met. Several systems were investigated as the primary technology for the needed upgrade. Among those considered were the Satellite Data Handling System (SDHS) at the Air Force Global Weather Central, Integrated Meteorological Processing System (IMPS) at the Western Test Range, Automated Forecast and Observing System (AFOS) of the National Weather Service, the Prototype Regional Observing and Forecasting Service (PROFS) being developed by NOAA at Boulder, Colorado, and the Man-computer Interactive Data Access System (McIDAS) at the Space and Science Engineering Center (SSEC) at the University of Wisconsin. The investigation of these systems led to a contract with the SSEC to develop a Meteorological Interactive Data Display System (MIDDS) as the core of the upgraded meteorological weather system to support the Shuttle. The MIDDS will provide the rapid data integration, display, and analysis capabilities needed to provide high quality forecasts to the Shuttle and will provide for a system which can be upgraded easily and inexpensively for future needs. The MSMP is also upgrading weather data inputs to

the MIDDS. These upgrades are discussed below:

a. Installed a new WSR-74C 5cm wavelength weather radar. This system detects precipitation rates as low as .01 in/hr and assists in preventing a launch through showers which could cause droplet erosion of Shuttle thermal protection system tiles.

b. Expanded the system of meteorological wind towers on the range (used primarily for toxic diffusion forecasts). The additional tower data will be processed in a new model that identifies small scale wind features likely to trigger or enhance thunderstorm formation.

c. Upgraded the lightning location system which is used to detect and pinpoint the location of cloud-to-ground lightning strikes to an accuracy of 300 ft. This enhances the safety of Shuttle external tank fueling operations.

d. Will add a processor to the new weather radar to allow plots of vertical and horizontal cross sections of the atmosphere. This will enable forecasters to see if the Shuttle launch or final approach flight paths will intersect storm cell echoes.

e. Added a Geostationary Operational Environmental Satellite (GOES) receiver system to the CCFS. This allows faster receipt of GOES data versus the previous method of receiving 20-30 minute old data via land-line sources. The in-house antenna system also adds the capability to receive 5 minute rapid-scan weather satellite photos during launch and landing operations.

SHUTTLE WEATHER CONSTRAINTS

As the Shuttle matures and its launch rate increases, weather and weather forecast accuracy will become two primary factors affecting Shuttle system scheduling and efficiency. As shown in table 2, weather impacts nearly all facets of Shuttle operations from rollover and rollout to final recovery of the Shuttle at end of mission. This table clearly illustrates the sensitivity of Shuttle operations to the environment and the subsequent impact of forecast support to maintaining Shuttle launch schedules. Table 3 lists weather impacts on previous Shuttle missions flown to date.

TABLE 2
STS WEATHER SENSITIVITIES

KSC Launch Site Constraints:

Temperature less than 31°F or greater than 99°F.
Precipitation forecast or occurring from the start of external tank loading through launch.
Ice accumulation on external tank greater than 1/16 inch.
Surface wind greater than 34 knots (peak) or 22 knots (steady state) from all azimuths (liftoff).
Prelaunch surface winds 49 knots steady state while on pad.

Severe Weather Constraints:

Flight within 5nm of the edge of a thunderstorm or within 3 miles of the associated anvil.
Flight through cumulus clouds with tops that exceed or are forecast to extend above the -10°C level.
When a 1000 volts/meter potential electric field contour encompasses the launch site.
Flight through clouds in the dissipating stage which have exceeded 1000 volts/meter within 15 minutes prior to launch.

Offshore Crew Recovery Area Constraints:

Surface wind greater than 25 knots.
Ceiling less than or equal to 500 feet.
Visibility less than or equal to 5 miles.
Seas greater than 8 feet.

Solid Rocket Booster (SRB) Recovery Area Constraints:

Sea state greater than sea state code 3 (3-5 foot moderate waves).
Visibility less than 15nm.
Cloud cover greater than 3 tenths.

Landing Sites Constraints:

Cloud cover greater than 5 tenths.
Visibility less than 7nm. Final launch decision relies on slant range evaluation by weather reconnaissance flights along the return to launch site path at KSC and reentry profile at Edwards AFB or White Sands.
Surface wind component (including max gusts) greater than 25 knots headwind, 10 knot crosswind, or 10 knot tailwind.
Any precipitation.
Turbulence greater than light to moderate.

Range Safety Constraints:

The ESMC Office of Range Safety also requires the following weather restrictions due to tracking and blast damage considerations:
Ceiling less than 1,000 foot.
Visibility less than 5nm.
Blast due to destruct sequence resulting in predicted fatality probability values greater than one in one hundred thousand will result in hold or scrub.

Shuttle Ferry Flight (Edwards AFB to KSC):

If the Shuttle lands at Edwards AFB instead of the Kennedy Space Center, the following

weather constraints apply to the return flight of the B-747 Shuttle Carrier Aircraft:

Flight conducted during daylight hours only.

No flight through visible moisture.

Flight level temperature must be greater than 15°F.

No turbulence greater than moderate.

Crosswinds must be less than 15kts for take-off and landings.

Runway ambient air temperature must be less than 92°F.

TABLE 3
WEATHER IMPACTS ON PREVIOUS SHUTTLE FLIGHTS

Mission	Weather Impact
STS-3	Landing site changed to White Sands Space Harbor because of standing water on Edwards AFB dry lake bed. Landing further delayed one day due to high winds at White Sands.
STS-7	Landing scheduled for KSC diverted to Edwards AFB due to unacceptable weather at the KSC Shuttle Landing Facility.
STS-8	Launch delayed 17 minutes due to the presence of thundershower activity at KSC.
41-C	KSC landing diverted to Edwards AFB due to forecast weather conditions being below acceptable landing limits at the Shuttle Landing Facility.
41-D	Return to KSC from Edwards AFB via Shuttle Carrier Aircraft delayed one day due to strong winds at KSC landing facility caused by Tropical Storm Diana.
51-A	Launch delayed one day due to strong upper air wind shears at KSC.

SYSTEM CONFIGURATION

The MIDDS system is shown in the figure 1 diagram. The full system configuration will include operational redundancy and will be in place by summer 1986.

FORECASTING BENEFITS OF THE SYSTEM

The following benefits result from the display and analysis capabilities of the MIDDS:

a. The local GOES earthstation provides forecasters with near realtime high resolution METSAT data, vice the 30 minute old data previously available via land facsimile network.

b. MIDDS enables the forecaster to do three-dimensional analysis of weather systems by using visual and IR METSAT.

c. Image enhancement and extended photo loops allow forecasters to time system movement and development more accurately.

d. With MIDDS, the forecasters are able to superimpose data sets to more easily evaluate total impact of all parameters.

e. The MIDDS enhances forecaster productivity by providing rapid machine generated analyses and allows the forecaster to spend more time studying the weather situation instead of doing manual plots and analysis of data.

FUTURE PLANS

The MIDDS is designed with a "bottom UP" philosophy. This design will allow easy modification of the system for tailoring to locally unique data sets, local area weather peculiarities and mission requirements. In this regard, the MSMP group hosted a workshop of government and university atmospheric scientists in the fall of 1984 to assist in preparation of a 5 year plan to fully utilize research projects underway and decide what is currently available as "off-the-shelf" weather technology. This plan is expected to be completed by May 1986. As of the writing of this article, KSC is awaiting bids from a proposal for "Weather Forecasting Expert Systems Evaluation and Feasibility". The stated final objective of the Weather Forecasting Expert System project is "---to capture the mesoscale/now-casting expertise and to have it resident in a set of expert system software, thus providing a real-time aid to new as well as experienced forecasters when under normal as well as stressed conditions. The project will also provide a system for training new weather forecasters in forecasting techniques for the endemic climatological conditions at the Kennedy Space Center. The existing forecasting expertise will be captured by incorporating the knowledge of the weather forecasting domain experts into an expert system set of software."

SUMMARY

This paper has provided the background and progress to date of upgrading weather support technologies to meet the challenge of Space Shuttle support. As shown, the maturation of Shuttle hardware will result in an increased system schedule that can only be met by minimizing the impacts of weather delays on all facets of Shuttle operations.

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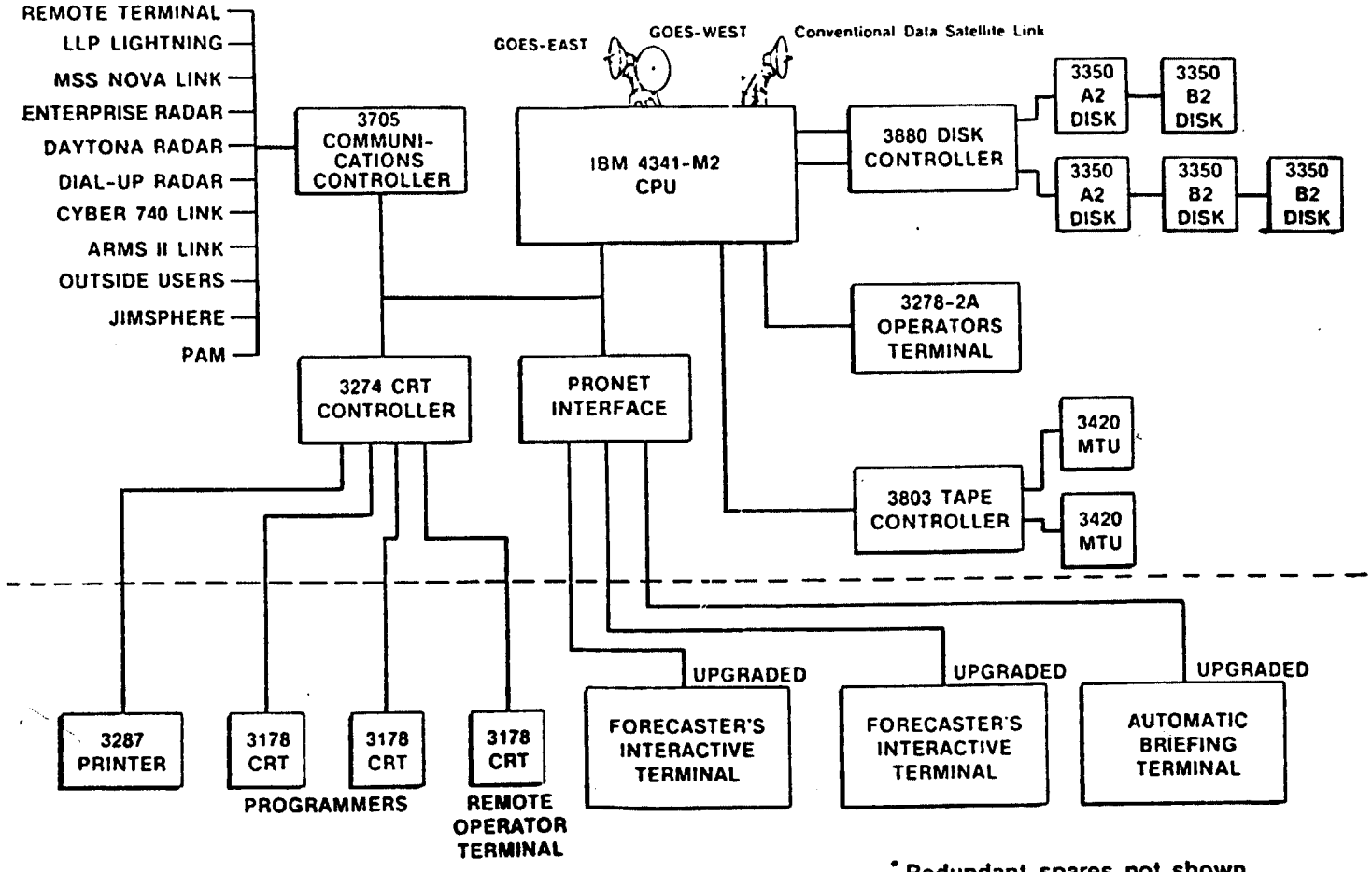
OPERATIONAL SYSTEM*



* Redundant spares not shown