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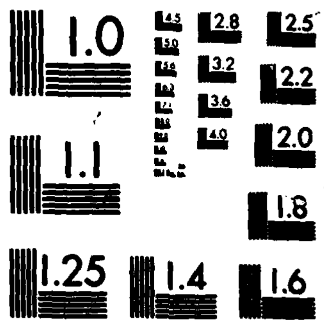

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STATUS REPORT ON THE APPLICATION OF THE METEOROLOGICAL INTERACTIVE DATA DISPLAY SYSTEM TO SPACE SHUTTLE AND RANGE SUPPORT AT THE KENNEDY SPACE CENTER AND CAPE CANAVERAL AFS

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1. Introduction

This 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 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 a normal end of mission landing at the Kennedy Space Center Shuttle Landing Facility.

2. Background

As the Shuttle hardware and operations mature, system turnaround time 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

With the projected schedule, it was evident that weather and weather support would become critical elements in achieving and maintaining this high launch rate. To deal with this problem, NASA and the USAF at the local level formed a joint Meteorological System Modernization Program (MSMP). This group is co-chaired by Technology Projects Office of Kennedy Space Center (NASA) and the Office of the Staff Meteorologist, Eastern Space and Missile Center (USAF). The purpose of this group is to upgrade the in-place forecast technology to ensure the challenges of Shuttle weather support are 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, the Integrated Meteorological Processing System (IMPS) at the Western Test Range, the 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) of the Space and Science Engineering Center (SSEC) at the University of Wisconsin. The review of these systems led to a contract with SSEC to develop a Meteorological Interactive Data Display System (MIDDS) as the core of the upgraded meteorological support system. The MIDDS provides the rapid data integration, display, and analysis capabilities needed to provide high quality forecasts to the Shuttle and the Eastern Test Range. It also provides a system that can be upgraded easily and inexpensively for future needs. Along with the MIDDS installation, the MSMP is also upgrading weather data inputs to MIDDS as follows:

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 would cause droplet erosion of Shuttle thermal protection system tiles.

b. Expanded the system of meteorological wind towers on the range (originally 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. This enhances the safety of Shuttle external tank fueling operations as well as the safety of crews working on gantries.

d. Will add a processor to the new weather radar to plot vertical and horizontal cross sections of the atmosphere. This will enable forecasters to see if the Shuttle launch or final approach flight path intersects storm cells.

e. Added a Geostationary Operational Environmental Satellite (GOES) receiver system to the CCFF. 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.

3. SHUTTLE WEATHER CONSTRAINTS

As Shuttle operations mature 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 in maintaining Shuttle launch schedules. Table 3 lists weather impacts on previous Shuttle missions flown to date.

TABLE 2

STS WEATHER SENSITIVITIES

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 greater than 1/16 inch on the external tank.

Surface winds greater than 34.4 knots (peak) or 22.6 knots (steady state) from all azimuths (lift off).

Prelaunch surface winds greater than 49 knots steady state while on the pad.

Upper air wind shears within Vehicle Load Limits.

Severe Weather Constraints:

Flight within 5nm of the edge of a thunderstorm or within 2nm of the associated anvil.

Flight through cumulus clouds with tops above or forecast to extend above the -20°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 0.5 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 1.5 miles.

Cloud cover greater than 3 tenths.

Landing (Return to Launch Site and End of Mission) Constraints:

Ceiling greater than 10,000 ft (8000 ft if Microwave Landing System (MLS) available).

Visibility less than 7 miles (5 mi if MLS). 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, 15 knots crosswind (RTLS), 10 knots crosswind (EOM), or 10 knots tailwind.

Any precipitation (RTLS), or precipitation within 50nm (EOM).

Turbulence greater than light to moderate.

Range Safety Constraints:

The ESMC Office of Range Safety also has restrictions under the following weather conditions, due to tracking and blast damage considerations:

Ceiling less than 1,600 feet.

Visibility less than 5 miles.

Blast due to destruct sequence resulting in predicted fatality probability values greater than one per 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 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 15 kts for takeoff and landing.

Take off 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 (ceiling and rainshowers) 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 (cloud cover) 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.
51-C	Temperatures below freezing were impacting external tank cryogenic loading.
51-D	Held to end of launch window by broken to overcast clouds over launch site.
51-D	Landing delayed one additional orbit due to isolated showers moving across KSC. Winds were at the crosswind limit during landing at KSC.

4. SYSTEM CONFIGURATION

The MIDDS system is shown in Figure 1. The full system configuration, including operational redundancy, will be in place by summer 1986.

5. 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 data.

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

d. With MIDDS, the forecasters are able to superimpose data sets to more easily evaluate the 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 analyses of data.

f. Most importantly, the MIDDS has greatly enhanced the confidence of our customers in the use of our forecasts. The ability to disseminate MIDDS output via closed circuit TV to system operators helps us to explain both our forecast reasoning and the current weather trends and thus bolsters the confidence of management in applying our forecasts in the launch and recovery decision process. To fully understand this, you need only place yourself in the situation of a launch director trying to make a decision based on a forecast using a hard copy, 30 minute old GOES photo covered with a grease pencil analysis compared to the high resolution looping/analysis capability provided by MIDDS and five minute rapid scan data.

6. Operational Application of the MIDDS

Examples of operational applications of the MIDDS are shown in Table 4. Although only available for a short time (system started as a remote terminal from SSEC in August 1984), the operational payoffs have been very significant.

TABLE 4

MIDDS APPLICATION TO RANGE OPERATIONS

TEST/SYSTEM	MIDDS APPLICATION/RESULT
Pershing II	METSAT loop and resolution indicated down range impact area clearing. 10 minute weather hold. ARIA aircraft confirmed forecast. Test conducted successfully. Saved rescheduling costs
STS-41-G Launch	MIDDS indicated RTLS clouds would remain thin and scattered variable broken. Launch conducted on time. Saved launch rescheduling costs.
STS-41G Recovery	MIDDS showed cloud cover would dissipate to acceptable level. EOM at KSC. Saved costs of Shuttle carrier aircraft flight.

TABLE 4 (cont)

MIDDS APPLICATION TO RANGE OPERATIONS

TEST/SYSTEM	MIDDS APPLICATION/RESULT
STS-51A	MIDDS showed clouds would remain thin and scattered-broken for recovery at KSC.
	EOM Recovery at KSC. Saved Shuttle carrier aircraft costs.
STS-51C	MIDDS IR METSAT analysis used to monitor local temperature trends. Surface temperatures below freezing were impacting external tank operations.
	Minimized delays on launch operations. Saved costs of additional rescheduling.
TITAN Launch	MIDDS showed clouds/showers moving north from south central Florida would slow and not reach the launch area.
	F-106 WX recon plane not required. Launch conducted on time. Saved WX recon costs.
ATLAS-CENTAUR INTELSAT-F10	MIDDS used to monitor development and track of low pressure system into SE United States.
	Launch was correctly delayed 24 hours based on weather forecast. Saved one day of additional range launch costs.
STS-51D (Launch)	MIDDS showed area of precipitation moving to south of Pad 39-A.
	Launch conducted at end of window, saved rescheduling costs.
STS-51D (Landing)	MIDDS and radar detected raincells moving in which would pass south of the Shuttle Landing Facility. MIDDS showed area of dry air moving in behind cells.
	EOM landing at KSC delayed one orbit to ensure safety of STS. Saved additional range costs of delaying extra day for EOM.
STS-51B	MIDDS streamline analysis capability used to assure launch officials that stratocumulus clouds over Melbourne and Orlando would not advect over RTLS.
	Prevented launch delay costs.

TABLE 4 (cont)

MIDDS APPLICATION TO RANGE OPERATIONS

7. FUTURE PLANS

The MIDDS is designed with a "bottom up" philosophy. This design allows 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. A follow-on workshop is scheduled for summer 1985. In May 1985, KSC contracted for a Weather Forecasting Expert System project "---to capture the mesoscale/nowcasting expertise and to have it resident in a set of expert system software, thus providing a realtime 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."

8. 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. Applications to date clearly demonstrate the payoff of the MIDDS system to range and Shuttle operational efficiency.

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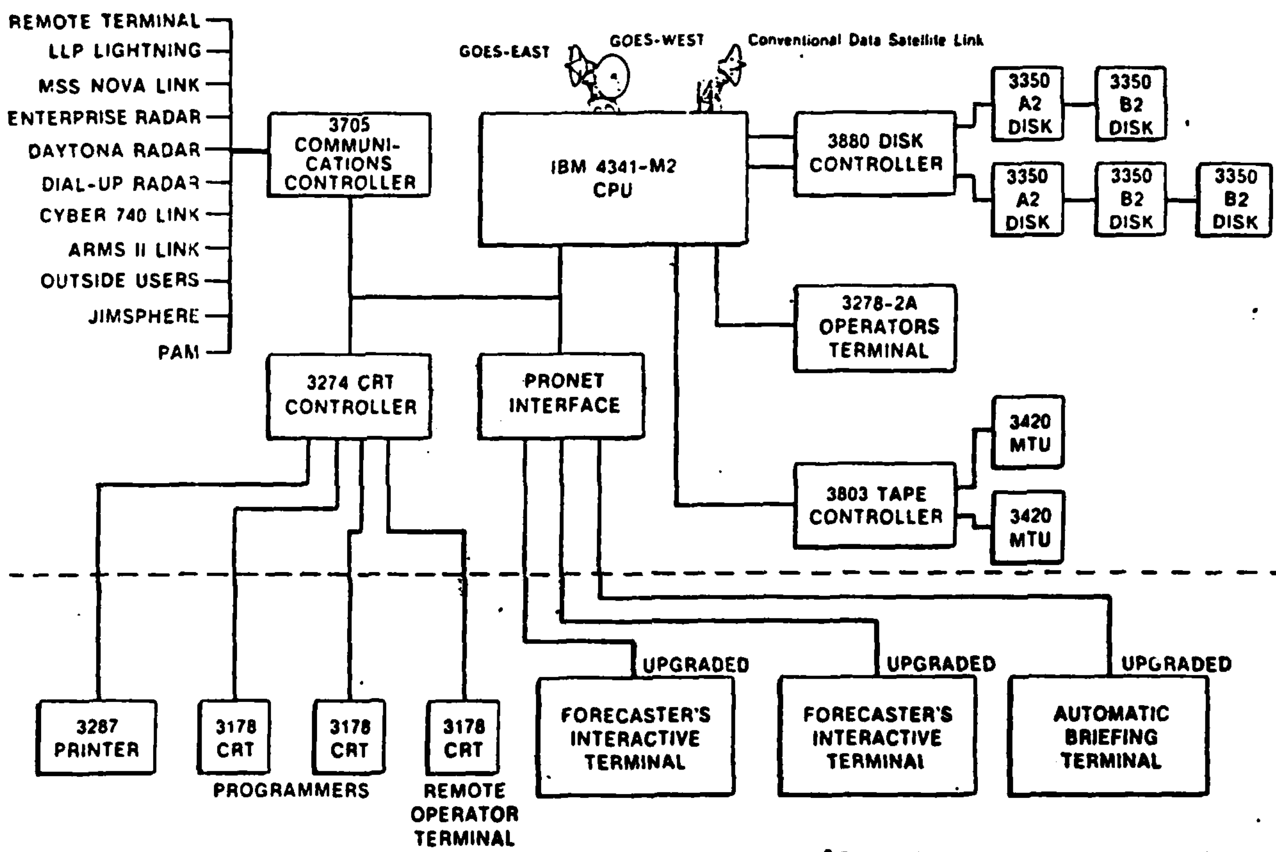
OPERATIONAL SYSTEM*



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