AD-A162 877 METEOROLOGICAL RANGE SUPPORT REQUIREMENTS AND IMPLICATIONS FOR THE FUTURE OF SHUTTLE OPERATIONS(U) EASTERN SPACE AND MISSILE CENTER PATRICK AFB FL 1/1

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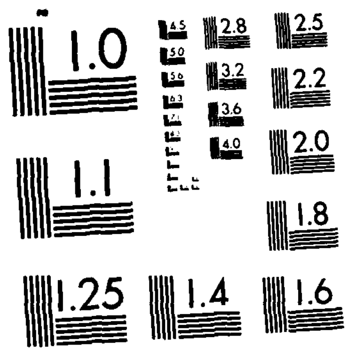

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The addition of a landing facility at the Kennedy Space Center (KSC) and an increased launch rate for the Space Shuttle required a significant change in meteorological requirements. The joint USAF-NASA efforts for improved support are discussed, including past efforts and future plans. Meteorological constraints to Shuttle operations are presented, forecasting benefits of the various systems are reviewed and weather impacts on specific missions are discussed.

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METEOROLOGICAL RANGE SUPPORT REQUIREMENTS AND IMPLICATIONS FOR THE FUTURE OF SHUTTLE OPERATIONS

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ABSTRACT

The addition of a landing facility at the Kennedy Space Center (KSC) and an increased launch rate for the Space Shuttle required a significant change in meteorological requirements. The joint USAF-NASA efforts for improved support are discussed, including past efforts and future plans. Meteorological constraints to Shuttle operations are presented, forecasting benefits of the various systems are reviewed and weather impacts on specific missions are discussed.

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	10
1986	17
1987	23*
1988	24*

*Includes 4 each year at Vandenberg AFB.

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 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 rain 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 WSR-74C 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 Cape Canaveral Forecast Facility (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.

SHUTTLE WEATHER CONSTRAINTS

As Shuttle operations mature and the 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, Winds, Presipitation

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 (measured at 60 feet above natural grade) 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 outside vehicle load limits.

Flightpath (Nominal or RTLS) Severe Weather Constraints (to protect the vehicle from lightning strikes)

Cannot be within 2NM above or 5NM horizontal distance of the anvil associated with a thunderstorm.

Cannot be through any cloud (convective or layered) from which precipitation (including virga) is observed.

Cannot be through clouds in the dissipating stage which have detected lightning by the electric field mill network within 15 minutes prior to launch.

Cannot be through any cloud if a 1000 volt per meter or greater ground level electric field contour encompasses launch (or landing) site.

Offshore Crew Recovery Area Constraints (from launch pad to 50NM in the Atlantic)

Surface wind greater than 25 knots.

Ceiling less than 500 feet.

Visibility less than 0.5NM.

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 1.5NM.

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

Ceiling less than 10,000 feet (8,000 feet if Microwave Landing System (MLS) available).

Visibility less than 7 miles (5 miles 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, 20 knots crosswind (lakebed), 15 knots crosswind (runway), 10 knots crosswind (EOM), or 10 knots tailwind.

Any precipitation (RTLS), or precipitation within 50NM (EOM at KSC).

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 Edward AFB instead of the Kennedy Space Center, the following weather constraints apply to the return flight of the NASA 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 knots for takeoff and landing.

Take off runway ambient air temperature must be less than 92°F.

TABLE 3

WEATHER IMPACTS ON SHUTTLE FLIGHTS THROUGH 15 OCT 85

Mission	Weather Impact
STS-3 22-30 Mar 82	Landing site changes to White Sands Space Harbor because of standing water on Edwards AFB dry lakebed. Landing further delayed one day due to high winds at White Sands.
STS-7 18-24 Jun 83	Landing scheduled for KSC diverted to Edwards AFB due to unacceptable weather (ceiling and rainshowers) at the KSC Shuttle Landing Facility.
STS-8 30 Aug-5 Sep 83	Launch delayed 17 minutes due to the presence of thundershower activity at KSC.
STS-41C 6-13 Apr 84	KSC landing diverted to Edwards AFB due to forecast weather conditions (cloud cover) being below acceptable landing limits at the Shuttle Landing Facility.
STS-41D 30 Aug-5 Sep 84	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.
STS-51A 8-16 Nov 84	Launch delayed one day due to strong upper air wind shears at KSC.
STS-51C 24-27 Jan 85	Temperatures below freezing were impacting external tank cryogenic loading.
STS-51D 12-17 Apr 85	Held to end of launch window by broken to overcast clouds over launch site.
STS-51D 12-17 Apr 85	Landing delayed one additional orbit due to isolated showers moving across KSC. Winds were at the crosswind limit during landing at KSC.
STS-51I 27 Aug 85-3 Sep 85	Launch scheduled for 24 Aug delayed 24 hours due to electrically active convective clouds in launch area.

SYSTEM CONFIGURATION

The MIDDS system is shown in Fig. 1. The full system configuration, including operational redundancy, 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 earth station provides forecasters with near real time 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 infrared (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 products and allows analysis of the weather situation instead of doing manual plots and hand 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.

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 (15 Aug 84-15 Oct 85)

TEST/SYSTEM	MIDDS APPLICATION/RESULT
Pershing II 3 Oct 84	METSAT loop and resolution indicated down range impact area clearing.
	Ten minute weatherhold. ARIA aircraft confirmed forecast. Test conducted successfully. Saved rescheduling costs.
STS-41G 5-13 Oct 84	MIDDS indicated RTLS clouds would remain thin and scattered variable broken. Launch conducted on time. Saved launch rescheduling costs.
STS-41G 5-13 Oct 84	MIDDS showed cloud cover would dissipate to acceptable level for EOM at KSC. Saved costs of Shuttle carrier operations.
STS-51A 8-16 Nov 84	MIDDS showed clouds would remain thin and scattered-broken for landing at KSC. EOM Recovery at KSC. Saved costs of Shuttle carrier aircraft operations.

STS-51C 24-27 Jan 85	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 21 Dec 84	MIDDS showed clouds/showers moving north from south central Florida would slow and not reach the launch area. F-106 weather reconnaissance plane not required. Launch conducted on time. Saved cost of weather reconnaissance flight.
ATLAS-CENTAUR INTELSAT-F10 9 Mar 85	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 12-17 Apr 85	MIDDS showed area of precipitation moving to south of Pad 39-A. Launch conducted at end of window, saved rescheduling costs.
STS-51D 12-17 Apr 85	MIDDS and radar detected rain-cells 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 29 Apr-6 May 85	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.
STS-51F 12 Jul 85 to abort	First Attempt MIDDS 1km resolution satellite data used to track convective activity in FL and assure launch officials that thunderstorms would not affect first afternoon launch attempt.
STS-51F 29 Jul-6 Aug 85	Launch Using MIDDS 1km satellite data and looping capability we were able to show launch officials weather would hold for launch period. Result: NASA extended opening of launch window to beginning of scientific window for maximum benefit of spacelab experiments.
STS-51I 27 Aug- 3 Sep 85	Scheduled 24 Aug but delayed due to weather on launch day. MIDDS used extensively to monitor and track severe weather associated with tropical wave. MIDDS corroborated radar data and tailored IR enhancements showed decreasing TRW tops. Shuttle was able to launch through a hole in the precipitation. Result: saved costly delays in rescheduling and recycling of external tank.
STS-51J 3-7 Oct 85	Easterly wave threatened launch, we were able to track its movement and dissipation, and we were able to show launch officials building cumulus fields (in rapid scan mode) and need for timely launch decision. Result: first flight of Atlantis on schedule.

FUTURE PLANS

Significant items planned for the MIDDS which should be in place within the next six months, and are shown on the operational system (Fig. 1) include the addition of radar and the National Meteorological Center's (NMC) product circuit. The radar data will include volumetric data using techniques developed by the McGill University radar group and will be patterned after their Short-Range Automated Radar Prediction (SHARP) system. This system will send Constant Altitude PPI (CAPPI) scans, arbitrary vertical slices, and short term forecasts of cell movement to the MIDDS from the WSR-74C radar.

The work station for the MIDDS is also being upgraded to a smart terminal with the IBM A/T as the nucleus. The software is designed with a "bottom-up" philosophy, allowing easy modification of the system for tailoring to locally unique data sets, local area weather peculiarities, and mission requirements.

The A. D. Little Company, Inc. has a six month contract with KSC for a "Weather Forecasting Expert System Evaluation and Feasibility". Results of this study are pending.

The Meteorological System Modernization Program (MSMP) is constantly reviewing current technology to assure both present and future requirements are met with the most modern methods possible.

SUMMARY

This paper has provided the background and progress to date of upgrading weather support technologies to meet the challenge of Space

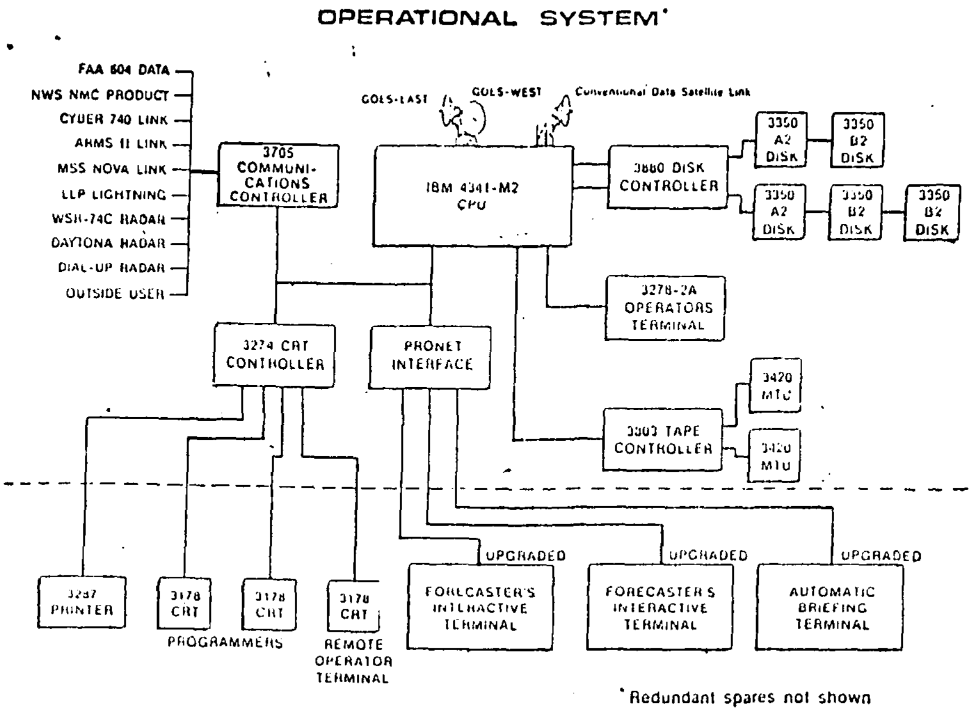

Fig. 1 MIDDS System Configuration

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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