Session IV. Sensor Fusion & Flight Evaluation

Integration of Weather Sensing Devices
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INTEGRATION OF WEATHER SENSING DEVICES

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ABSTRACT

The state of airborne atmospheric sensing is continually evolving as devices are developed which further enhance the detection of meteorological phenomena. Assuming that these technologies prove to be feasible, the greatest long-term benefit would be attained by effective integration of the various sensors. A system which could accomplish this goal would conceivably provide enhanced atmospheric analysis, coherent display capability, and would allow for the development of expert systems to predict weather conditions.

This presentation briefly outlines the existing and developing weather detection technologies, followed by an overview of what issues must be dealt with in the creation of an integrated system. The presentation concludes with a framework of a basic system which identifies some of the potential applications that exist.

INTEGRATION OF WEATHER SENSING DEVICES

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INTRODUCTION
(WHY INTEGRATE?)

AS ADDITIONAL DEVICES WHICH AID IN THE DETECTION OF ADVERSE ATMOSPHERIC PHENOMENA BECOME AVAILABLE, THE ISSUE OF HOW TO EFFECTIVELY INTEGRATE THE VARIOUS TECHNOLOGIES NEEDS TO BE ADDRESSED.

ALL THE VARIOUS TECHNOLOGIES HAVE POSITIVE CONTRIBUTIONS TO MAKE IN THE AREA OF HAZARDOUS WEATHER DETECTION AND AVOIDANCE. THE EFFECTIVE INTEGRATION OF THESE TECHNOLOGIES INTO A CONCISE SYSTEM WILL PROVIDE THE GREATEST LONG TERM BENEFIT.

OVERVIEW

- o Intent is mainly to present issues.
  - Not absolute system definition.
- o Focus is integration of devices which sense atmospheric conditions.
  - Presently implemented as well as developing technologies.
- o Issues affecting an integrated system.
  - Data processing.
  - Data presentation.
- o Basic integrated meteorological system.

BACKGROUND

o ORIGINALLY, NO WEATHER SENSORS ON AIRCRAFT.

- THE NEED FOR ACCURATE WEATHER INFORMATION BECAME NECESSITATED DUE TO AIRCRAFT DAMAGE AND LOSS RESULTING FROM ATMOSPHERIC CONDITIONS.

o PRESENTLY IMPLEMENTED AIRBORNE TECHNOLOGIES:

- WEATHER RADAR
  * RAINFALL LOCATION AND INTENSITY.
  * TURBULENCE ASSOCIATED WITH RAINFALL.
  * LIGHTNING (OPTIONAL).
    DISPLAYED ON WEATHER RADAR SCREEN.

- PRECISE WIND MEASUREMENT AT AIRCRAFT
  * REQUIRES PRECISE GROUND SPEED MEASUREMENT.

- REAC IVE WINDSHEAR SYSTEMS
  * ALERTS PILOT WHEN A WINDSHEAR IS EXPERIENCED.

BACKGROUND

o Developing Airborne Technologies:

- Doppler Radar
  * Look-Ahead windshear detection.
  * Remote wind measurement.

- LIDAR
  * Look-Ahead windshear detection.
  * Remote wind measurement.
  * Look-Ahead CAT detection.
  * Wake turbulence detection.

- Infrared/Look-Ahead Temperature Sensing
  * Look-Ahead windshear detection.
  * Look-Ahead CAT detection.

FORWARD LOOKING WEATHER DETECTION TECHNOLOGIES

	DOPPLER RADAR	LIDAR	PASSIVE INFRARED
WIND MEASUREMENT	RAINDROP TRACERS	AEROSOL TRACERS	THERMAL GRADIENT
TECHNOLOGY	o NEW GENERATION WEATHER RADAR	o SOLID STATE AND GAS LASERS	o NEW GENERATION SENSORS
TECHNOLOGY READINESS	NEAR FUTURE	NEAR FUTURE	IN HAND
PERFORMANCE	o GROUND BASED EXPERIENCE o NASA FLIGHT TEST	o NASA FLIGHT TEST	o ACTUAL MICROBURST DETECTION
WET MICROBURST	GOOD	POOR	MARGINAL TO GOOD
DRY MICROBURST	POOR	GOOD	GOOD
ADVANTAGES	o COULD COMPLEMENT WEATHER RADAR USING EXISTING RADOME, DISPLAY, ETC.	o CAT DETECTION o ENROUTE WINDS o WAKE TURBULENCE	o LEAST COMPLEX o INEXPENSIVE o CAT DETECTION o PASSIVE SYSTEM
MAJOR TECHNICAL PROBLEMS/RISKS	o REMOVING GROUND CLUTTER o DRY MICROBURST o TILT MANAGEMENT o VERT. WIND MEASUREMENT	o HARDWARE COMPLEXITY/COST o MAINTENANCE o LASER LIFE o OPERATION IN HEAVY RAIN o VERT. WIND MEASUREMENT o WEIGHT o POWER REQUIREMENTS	o INFERENTIAL o NUISANCE DET. o HORIZ. WIND MEASUREMENT o DEGRADATION IN RAIN o MAINTENANCE

TECHNOLOGY SUMMARY

THE EXISTING STATE OF ON-BOARD DETECTION OF ADVERSE ATMOSPHERIC PHENOMENA COULD BE SIGNIFICANTLY ENHANCED BY THE INCLUSION OF SOME OR ALL OF THE DEVELOPING TECHNOLOGIES.

- NONE OF THE THREE FORWARD LOOKING TECHNOLOGIES HAS YET BEEN PROVEN TO BE A UNIVERSAL SOLUTION FOR DETECTION OF ADVERSE WEATHER.
- WHERE ONE TECHNOLOGY MAY SUFFER, ANOTHER MAY EXCEL.
- THE IDEAL METEOROLOGICAL SYSTEM WILL CONTAIN MORE THAN ONE OF THESE TECHNOLOGIES COMPLEMENTING ONE ANOTHER.

DEVELOPMENT ISSUES

IN ORDER TO DEVELOP A SYSTEM WHICH INCORPORATES INPUTS FROM THE VARIOUS WEATHER SENSING DEVICES, THE FOLLOWING ISSUES MUST BE ADDRESSED:

- HOW IS DATA ASSIMILATED FROM THE MULTIPLE SENSORS?
- HOW IS DATA PRESENTED TO THE PILOT IN A CONCISE MANNER?
- WHAT OTHER POTENTIAL APPLICATIONS MAY EXIST?

DEVELOPMENT ISSUES

HOW IS DATA ASSIMILATED FROM THE MULTIPLE SENSORS?

o DISTRIBUTED SYSTEM.

- EACH SENSOR WITH COMPUTATIONAL CAPABILITY.
- RELEVANT DATA TRANSMITTED TO OTHER DEVICES.
- DISPLAY OPTIONS:
  * INDIVIDUAL DISPLAYS FOR EACH SENSOR.
  * CENTRAL DISPLAY UNIT PROCESSING OUTPUTS FROM THE SENSORS.

o INTEGRATED SYSTEM.

- CENTRALIZED PROCESSING OF SENSOR INPUTS.
- SENSORS ACT IN COMPLEMENTARY FASHION TO ONE ANOTHER.
- ENHANCED ATMOSPHERIC ANALYSIS.
- SINGLE, MULTI-FUNCTION DISPLAY.
- CAPABILITY FOR FORECASTING (EXPERT SYSTEM).

DEVELOPMENT ISSUES

How is data presented to the pilot in a concise manner?

- o Present data for pilot evaluation.
  - E.g. Weather Radar.
- o Notify pilot of significant events.
  - E.g. Windshear Alert.
- o Provide forecast of adverse weather risk for pilot evaluation.
  - "Meteorologist in the cockpit" (Expert System).
- o Combination system.
  - Integrated meteorological system based on combination of the above data presentation formats.

DEVELOPMENT ISSUES

ANY OTHER POTENTIAL APPLICATIONS?

o REPORTING DATA TO GROUND STATIONS FOR USE BY OTHER AIRCRAFT.

  - METHOD FOR COMMUNICATING THE DATA REQUIRED.
  - SYSTEMS TO ACCUMULATE/REDUCE THE DATA.

o OTHER WEATHER PHENOMENA THAT PILOT WOULD LIKE TO KNOW IN REAL TIME?

  - ICING CONDITIONS.
  - RAIN RATE AT THE AIRCRAFT - AOA/STALL EFFECTS.
  - CHANGING WEATHER PATTERNS.

o INTERFACING WEATHER DATA TO OTHER AIRCRAFT SYSTEMS.

  - ALTER FLIGHT PLAN BASED ON IMPENDING WEATHER CONDITIONS.
  - GUIDANCE TO ESCAPE ADVERSE SITUATIONS.
  - AUTOMATIC ACTIVATION OF DE-ICING SYSTEMS.
  - ETC..

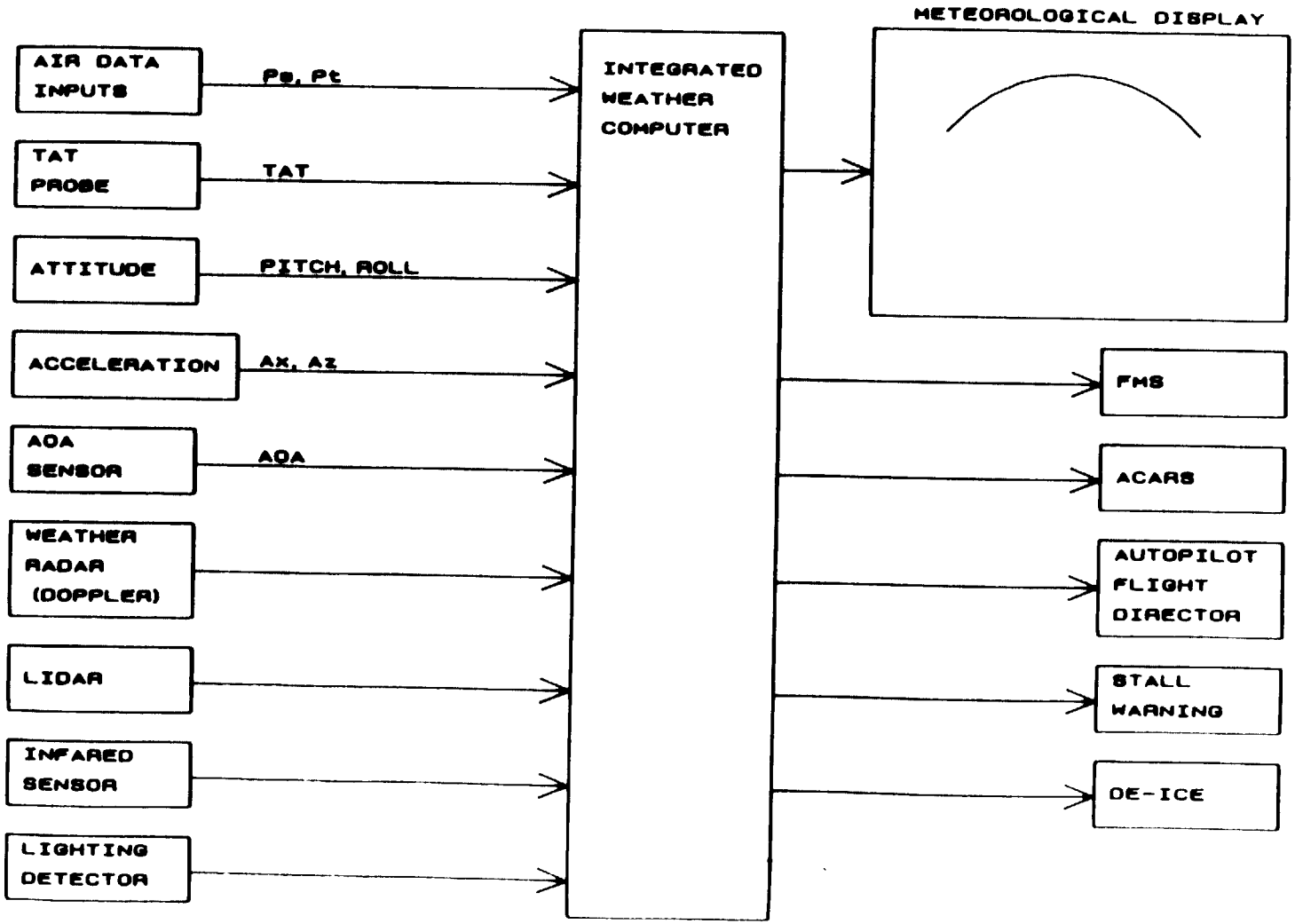
BASIC ASSUMPTIONS

- INTEGRATION OF THE VARIOUS WEATHER SENSORS IS MORE ADVANTAGEOUS THAN INDIVIDUAL COMPONENTS WORKING INDEPENDENTLY.
- SINGLE PROCESSING UNIT PROVIDES GREATEST CAPABILITY.
- SINGLE, MULTI-FUNCTION DISPLAY IS DESIREABLE.
- DISPLAY SHOULD:
  - * SHOW THE PILOT WHAT CONDITIONS ARE PRESENT.
  - * ALERT WHEN A DANGEROUS CONDITION EXISTS.
  - * PROVIDE WEATHER FORECASTING.
- SYSTEM SHOULD PROVIDE OUTPUTS FOR USE BY OTHER AIRCRAFT SYSTEMS.

INTEGRATED METEOROLOGICAL SYSTEM

- INTEGRATED WEATHER COMPUTER RECEIVING INPUTS FROM THE VARIOUS ATMOSPHERIC AND AIR DATA SENSORS.
- EXPERT SYSTEM UTILIZING THE VARIOUS INPUTS TO PREDICT WEATHER EVENTS AS WELL AS IDENTIFY EXISTING PHENOMENA.
- METEOROLOGICAL DISPLAY WITH GRAPHICAL REPRESENTATION OF THE VARIOUS WEATHER OCCURRENCES IN ADDITION TO TEXT DISPLAYS OF PERTINENT WEATHER-RELATED DATA.
- OUTPUTS FOR USE BY OTHER AIRCRAFT SYSTEMS.

INTEGRATED METEOROLOGICAL SYSTEM



INTEGRATED METEOROLOGICAL SYSTEM
POTENTIAL BENEFITS

- o METEOROLOGICAL DISPLAY
  - PROVIDE RELEVANT DATA TO THE COCKPIT.
- o FLIGHT MANAGEMENT SYSTEM (FMS)
  - ALTER FLIGHT PLAN BASED ON HAZARD AVOIDANCE.
  - ALTER FLIGHT PLAN BASED ON DETECTED WINDS WHICH MAY REPRESENT A PERFORMANCE INCREASE.
- o GROUND COMMUNICATION (ACARS)
  - AUTOMATIC COMMUNICATION OF ATMOSPHERIC DATA TO GROUND STATIONS FOR SUBSEQUENT RELAY TO OTHER AIRCRAFT WHICH MAY ENCOUNTER DETECTED HAZARDOUS CONDITIONS.

INTEGRATED METEOROLOGICAL SYSTEM POTENTIAL BENEFITS (CONT.)

- o AUTOPILOT/FLIGHT-DIRECTOR
  - PROVIDE GUIDANCE TO AVOID/ESCAPE A HAZARDOUS WEATHER CONDITION.
- o STALL WARNING
  - AUTOMATIC ADJUSTMENT OF STICK-SHAKER AOA BASED ON RAIN RATE.
- o DE-ICE/ANTI-ICE
  - AUTOMATIC ACTIVATION OF DE-ICE AND ANTI-ICE EQUIPMENT WHEN ICING CONDITIONS EXIST.
- o ETC..

INTEGRATED METEOROLOGICAL SYSTEM
EXPERT SYSTEM

THE EXPERT SYSTEM RESIDING IN THE WEATHER COMPUTER WILL PERFORM ANALYSIS OF CURRENT INPUTS TO DETERMINE IF HAZARDOUS ATMOSPHERIC CONDITIONS ARE PRESENT:

- o WINDSHEAR
- o UNSTABLE AIRMASS
- o HEAVY RAINFALL
- o TURBULENCE
- o LIGHTNING
- o STRONG WINDS

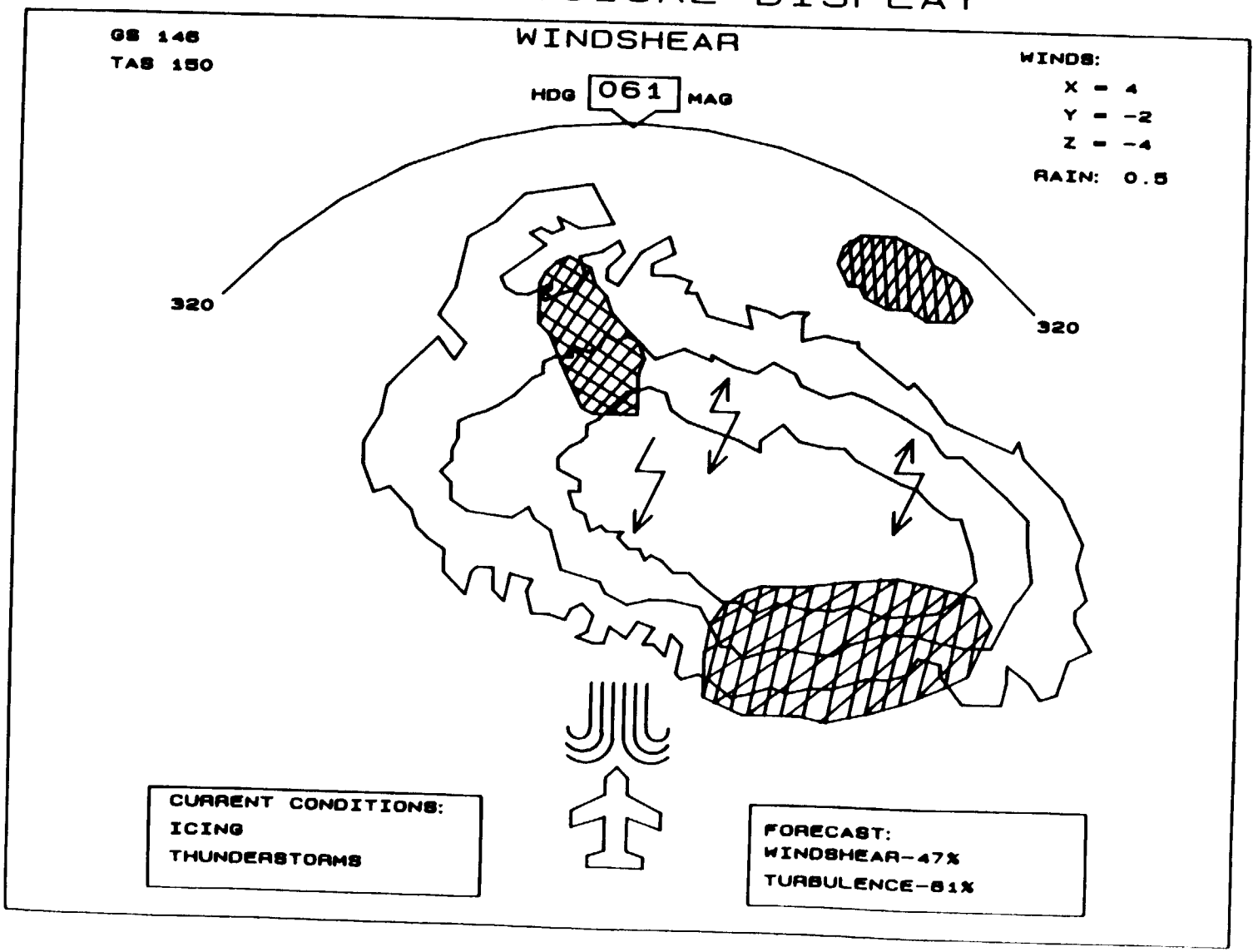
THE SYSTEM WILL ALSO PROVIDE A PROBABILISTIC ANALYSIS OF CURRENT CONDITIONS IN ORDER TO PREDICT THE LIKELIHOOD OF THE AIRCRAFT ENCOUNTERING AN UNSAFE SITUATION IN THE CURRENT FLIGHT PATH.

INTEGRATED METEOROLOGICAL SYSTEM DISPLAY

THE MULTI-FUNCTION, METEOROLOGICAL DISPLAY WILL PROVIDE PERTINENT ATMOSPHERIC DATA TO THE COCKPIT IN A CONCISE, INFORMATIVE MANNER USING GRAPHICAL, TEXT, AND PICTORIAL FORMATS.

- DISPLAY FORECASTED WEATHER CONDITIONS.
- DISPLAY OF CURRENT ATMOSPHERIC STATUS IN THE IMMEDIATE VICINITY OF THE AIRCRAFT.
- DISPLAY OF DETECTED WEATHER CONDITIONS.
- ALERT OF CONDITIONS WARRANTING IMMEDIATE PILOT ATTENTION (E.G. WINDSHEAR).

METEOROLOGICAL DISPLAY



SUMMARY

- Current emphasis is individual sensors which detect atmospheric conditions.
- Next-Generation implementation:
  - Integration of the multiple sensors.
    - * Maximizes the benefits of each.
    - * Minimizes the individual shortcomings.
    - * Supports coherent, multi-function display techniques.
    - * Provides additional capabilities.

Integration of Weather Sensing Devices - Questions and Answers

Q: BERNARD SILVERMAN (Active EO Systems Analyses) - What is the basis for the statement that LIDAR is poor in rain? Is there any good data?

A: JIM DAILY (Honeywell Sperry) - The ranking of LIDAR as "poor" in rain is due to information based on the Lockheed CO_2 laser. The signal is absorbed by rain and therefore the signal is significantly attenuated. This translates to a loss of range during severe rain conditions. The majority of data supporting this is as presented in Russel Targ's presentation. "Poor" only relates to the ability of the LIDAR system to penetrate heavy rain, not its ability to identify the edge of the hazard.