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Session IV. Sensor Fusion & Flight Evaluation

N91-24175

NASA Langley Flight Test Program
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NASA/LANGLEY RESEARCH CENTER

WINDSHEAR FLIGHT PROJECT

GENERAL OVERVIEW

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WINDSHEAR FLIGHT TEST
PROJECT ENGINEER
10/16/90

OUTLINE

- PROGRAM OVERVIEW
- FLIGHT TEST OBJECTIVE
- FACILITY
- FLIGHT REQUIREMENTS
- FLIGHT OPERATIONS
- STATUS/SCHEDULE

NASA

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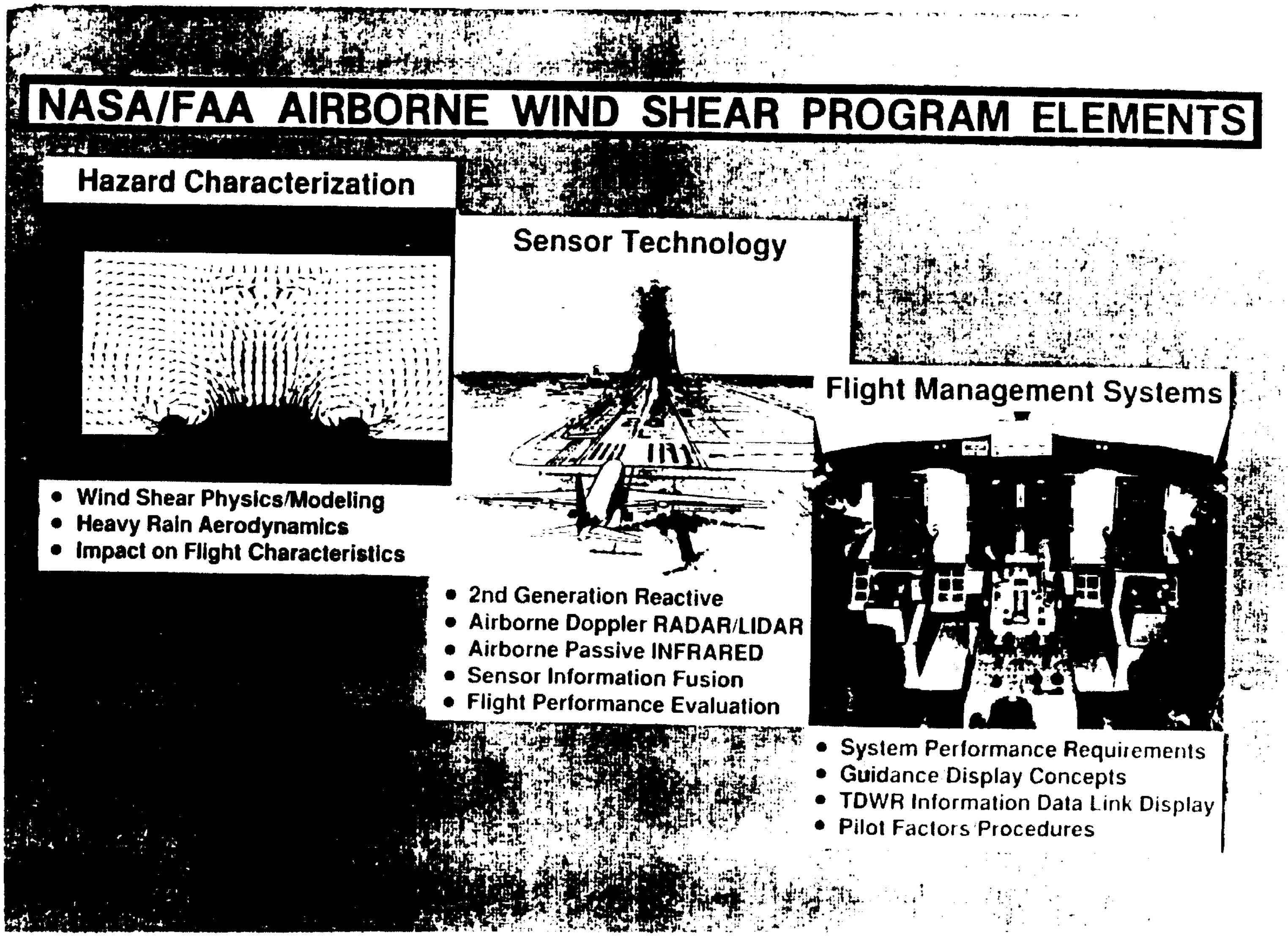

FLIGHT TEST OBJECTIVE

Safely
develop, refine, validate and demonstrate
advanced windshear sensor technologies and
associated pilot/vehicle interface
in a representative range of
meteorological and other operational environments
and in a timely, cost effective manner.

DEFINITIONS

- safely: No additional risk to aircraft or crew than current ATOPS/airline operations
- validate: Establish final performance levels against functional requirements and success criteria for each sensor subsystem.
- demonstrate: Effectively exhibit system operation and performance in flight to appropriate industry, government, and other organizations.
- variety of advanced windshear sensor technologies: Infrared, Doppler radar, in situ, Doppler Lidar, TDWR ground system airborne linkage
- associated pilot/vehicle interface: The crew warnings and displays, and guidance and control system interaction required for operational utilization of the sensor data for each sensor subsystem and practical sensor combinations.
- representative range: With enough variation to establish airborne system performance sensitivities to major variables and enable validation of ground simulation models.
- timely: On current schedule and responsive to FAA rulemaking and equipment installation timetables
- cost effective: On current budget

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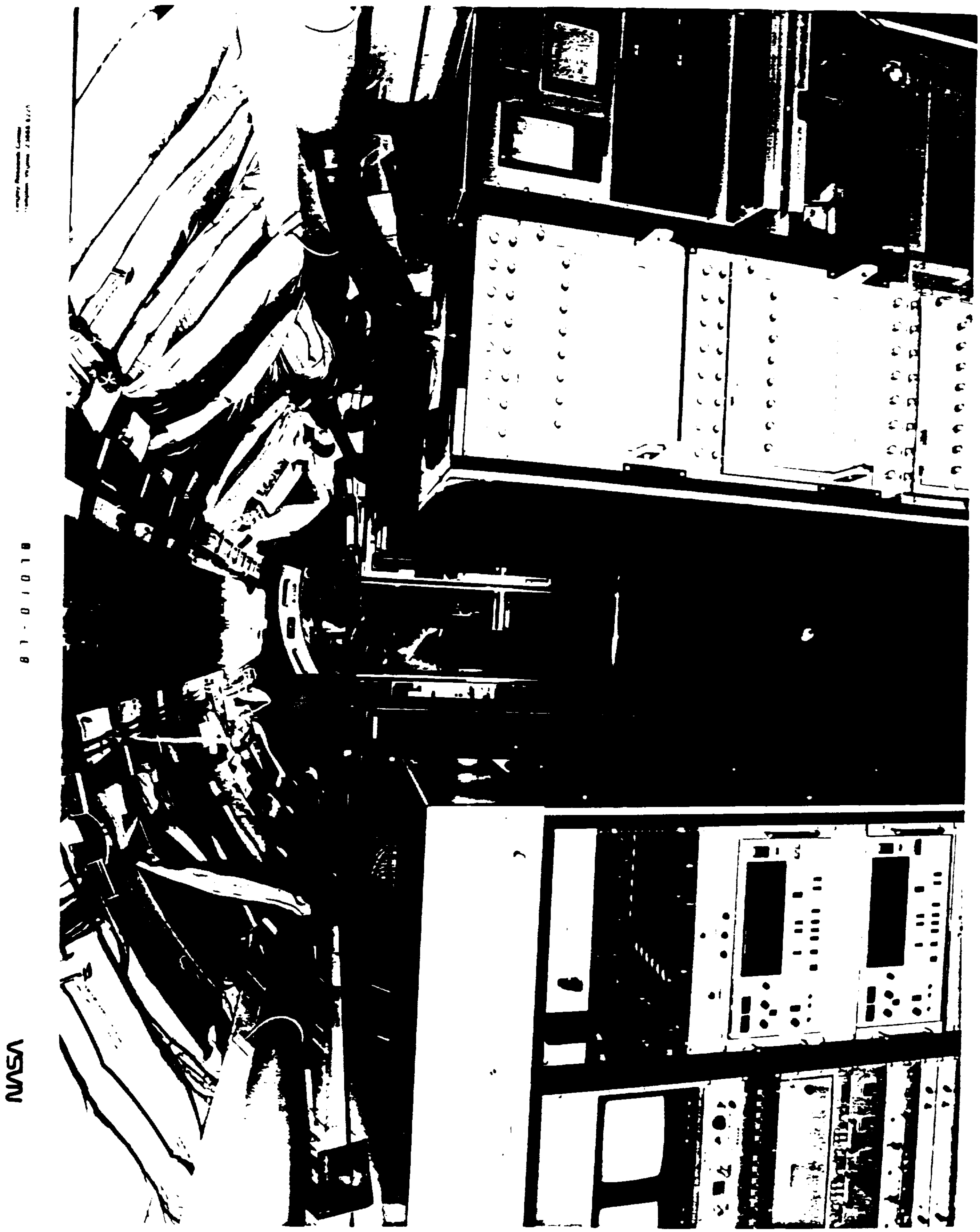

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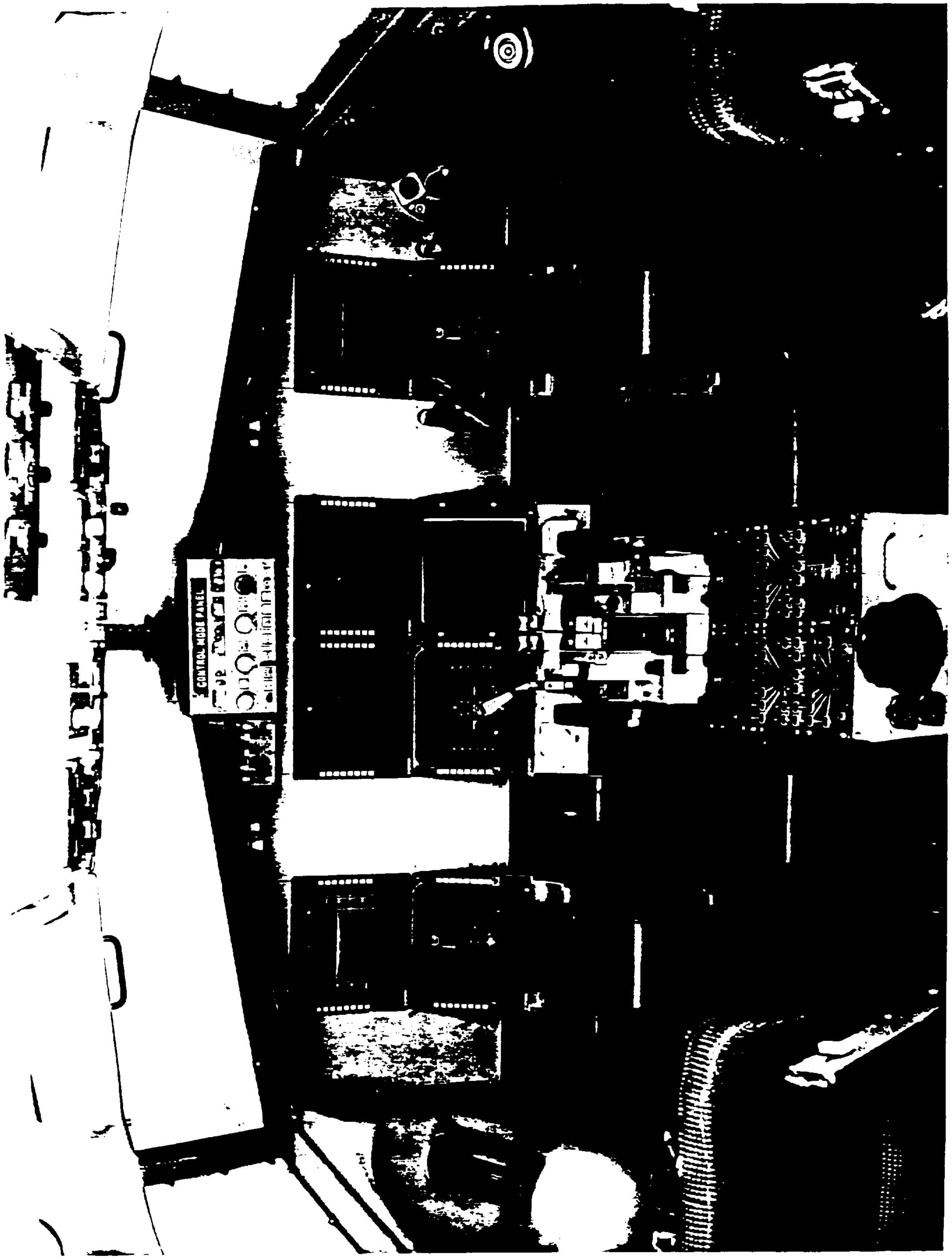
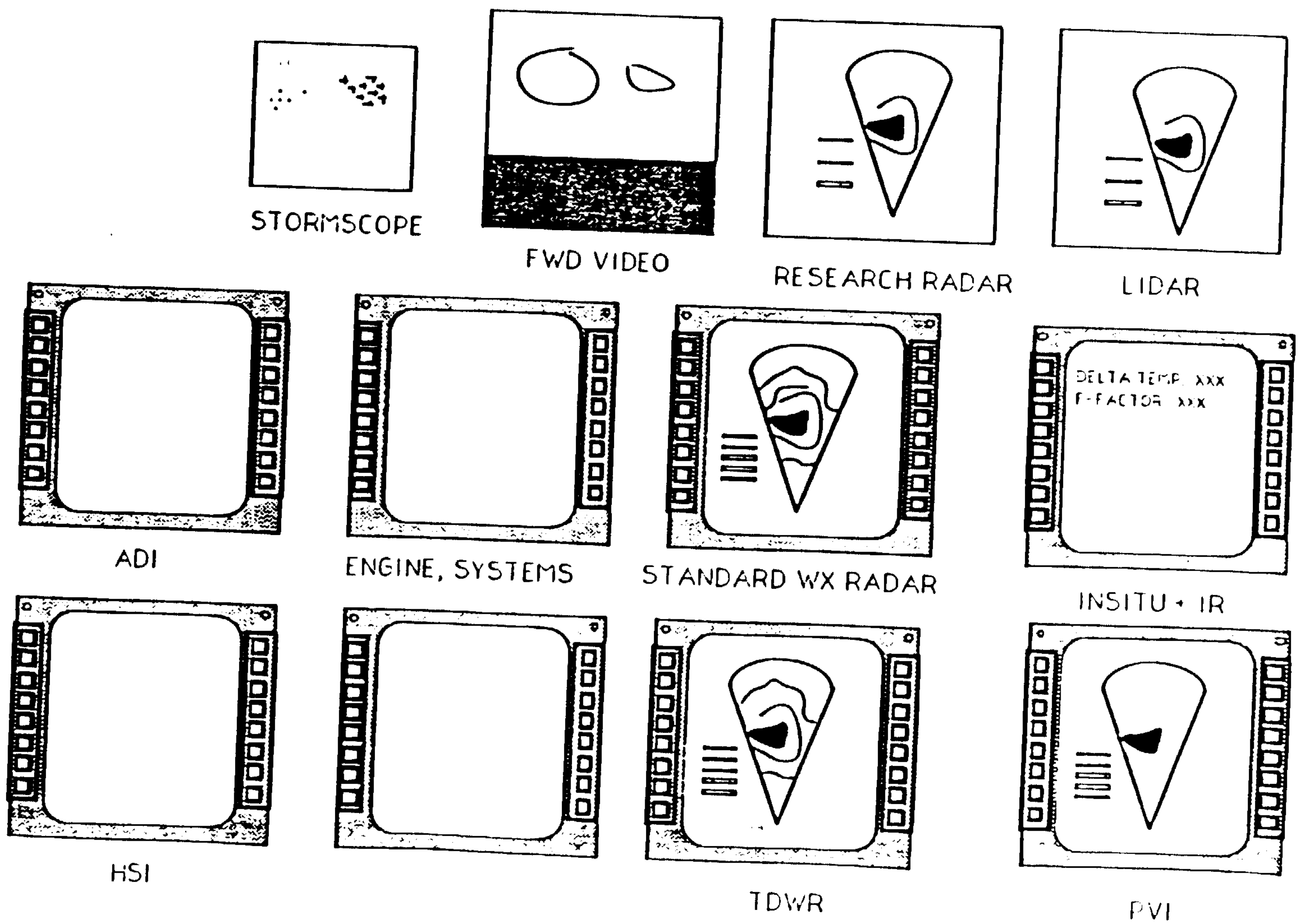


WINDSHEAR FLIGHT PROJECT

RFD INTEGRATED MONITORING STATION



FLIGHT REQUIREMENTS

0.) HARDWARE CHECKOUT

1.) TEST TYPE I AND TYPE II ERRORS
- PROB OF DETECTION: NEED MICROBURST EVENT
- PROB OF FALSE ALARM: NEED OTHER WX, GROUND CLUTTER, A/C MANEUVERS

2.) DEVELOP AND EVALUATE TDWR DATA LINK

3.) DEVELOP AND EVALUATE PVI/SENSOR INTEGRATION CONCEPTS

4.) DEMONSTRATE ABOVE TO INDUSTRY, GOV'T, PUBLIC

5.) DO IT ON TIME

EXTERNAL EXPERIMENTAL PARAMETERS

WEATHER
- WET AND DRY MICROBURSTS (<.15 SAMPLE; >.15 STAND-OFF)
- GUST FRONTS (MED TO STRONG)
- SEA BREEZES (MED TO STRONG)
- RAIN (HIGH HUMIDITY TO 60 DBZ)
- TURBULENCE (LIGHT TO MODERATE)
- INVERSIONS (MODERATE TO STRONG)

A/C MANEUVERS
- NORMAL TAKEOFFS AND APPROACHES
- LEVEL AND TURNING FLIGHT ACCELERATIONS
- LOW LEVEL FLIGHT

GROUND FEATURES
- FIXED CLUTTER (~14 DISTINCT TYPES)
- MOVING CLUTTER

WINDSHEAR FLIGHT PROJECT

TEST SITE SELECTION

THREE SITES FULFILL ALL REQUIREMENTS:

- LOCAL: CONVECTION, FRONTS, SEA BREEZES, HIGH HUMIDITY, WET MICROBURSTS (STAND-OFF), RAIN, CLOUDS, CLEAR, HAZE
- DENVER: DRY MICROBURSTS, INVERSIONS, HIGH BASE ALTITUDE, LOW HUMIDITY
- ORLANDO: WET MICROBURSTS, CONVECTION, SEA BREEZES, RAIN

WINDSHEAR FLIGHT PROJECT

MICROBURSTS/GUST FRONTS
ORLANDO, FL
6/2 - 7/13, 1990

S	M	T	W	T	F	S
						4/0
10/3	6/1	18/1	11/1	8/1	7/2	9/3
0	0	0	0	0	0	0
9/3	4/1	0/2	2/0	11/0	5/1	3/1
8/2	16/3	7/4	0	0	0	10/1
12/3	6/4	1/0	13/1	0	1/1	10/2
9/3	15/2	0	11/3	20/5	10/2	

- **MICROBURSTS**

6 WEEKS; 256 TOTAL; 6.2 DAY; 4.8 DAYS/WEEK

- **GUST FRONTS**

6 WEEKS; 55 TOTAL; 1.3/DAY; 4.3 DAYS/WEEK

- **DENVER DATA SIMILAR**

WINDSHEAR FLIGHT PROJECT

FLIGHT OPERATIONS OVERVIEW

FLIGHT REQUIREMENT	FLIGHT OPERATIONS REQ'T
0.) H/W CHECKOUT	0.) FLIGHT TIME ONLY
2.) TEST TDWR DATA LINK	2.) FLIGHT TIME ONLY
3.) TEST PVI CONCEPTS	3.) FLIGHT TIME GENERALLY
4.) DEMONSTRATE	4.) FLIGHT TIME GENERALLY

THE REAL PROGRAM CHALLENGE. . .

1.) TEST FOR TYPE I AND TYPE II ERRORS	1.) WEATHER, TIMING, PERFORMANCE, COMMUNICATIONS, PLANNING AND PREPARATIONS

TYPE I, II ERROR TESTING

- NEED TO CONFIRM PREDICTED MEASUREMENTS (INCLUDING TDWR) WITH A/C IN SITU DATA
  - MICROBURST MEASUREMENT REQUIRED
  - STATISTICAL SAMPLING IMPRACTICAL AND UNNECESSARY (GROUND SIMULATION ROLE)

GOAL IS HANDFUL OF SUCCESSFUL PREDICTIONS WITH RIGOROUSLY TESTED LOW FALSE ALARM RATE

- 3 DIFFICULTIES
  - NEED WEATHER COORDINATION
  - NEED SAFETY PLAN
  - NEED OPERATIONS PLAN

SAFETY

GENERAL GUIDELINES

1.) MINIMIZE WEATHER EXPOSURE

2.) ESTABLISH OPERATIONAL LIMITS AND PROCEDURES

3.) MINIMIZE LIGHTNING EFFECTS

4.) MAINTAIN COMMUNICATIONS WITH GROUND SUPPORT

5.) FLIGHT CREW TRAINING

6.) PHASED APPROACH

WINDSHEAR FLIGHT PROJECT

SAFETY

ESTABLISH OPERATIONAL LIMITS AND PROCEDURES

Preliminary:

ALTITUDE: > 750 FT AGL WITH F-FACTOR > .10
AIRSPEED: > 200 KIAS WITH F-FACTOR > .10
F-FACTOR: WITHOUT TDWR: < .10
WITH TDWR: < .15
LIGHTNING: REMAIN CLEAR OF OBSERVED SEVERE ACTIVITY
REFLECTIVITY: < 40 DBZ
HAIL: WITHOUT TDWR: NO ANVIL UNDERFLIGHTS
WITH TDWR: NO FLIGHT THROUGH PREDICTED HAIL REGION
WEATHER RADAR: REQUIRED SCAN ALWAYS AVAILABLE TO FFD
GROSS WEIGHT: SET LIMIT IF INDICATED THROUGH SIMULATION
PROCEDURAL: FFD CONTROL FOR ALL SHEAR MEASUREMENTS
FUEL RESERVE FOR DIVERSION
PRE-FLIGHT GROUND OBSTACLE IDENTIFICATION
MEASUREMENT OF ISOLATED EVENTS ONLY, CLEAR EXIT ROUTE IDENTIFIED
IMS AFT FLIGHT DECK MONITORING OF ALL LIMITS

SAFETY

PHASED APPROACH

- WINDSHEAR MEASUREMENTS ARE INTENDED TO INCREASE TO FULL LIMITS IN STAGES:
  - 0 - 0.075
  - 0.075 - 0.10
  - 0.10 - 0.12
  - 0.12 - 0.15

ALL MEASUREMENTS ARE SUBJECT TO FINAL DECISION OF THE FLIGHT CREW

SAFETY

<u>SUMMARY</u>

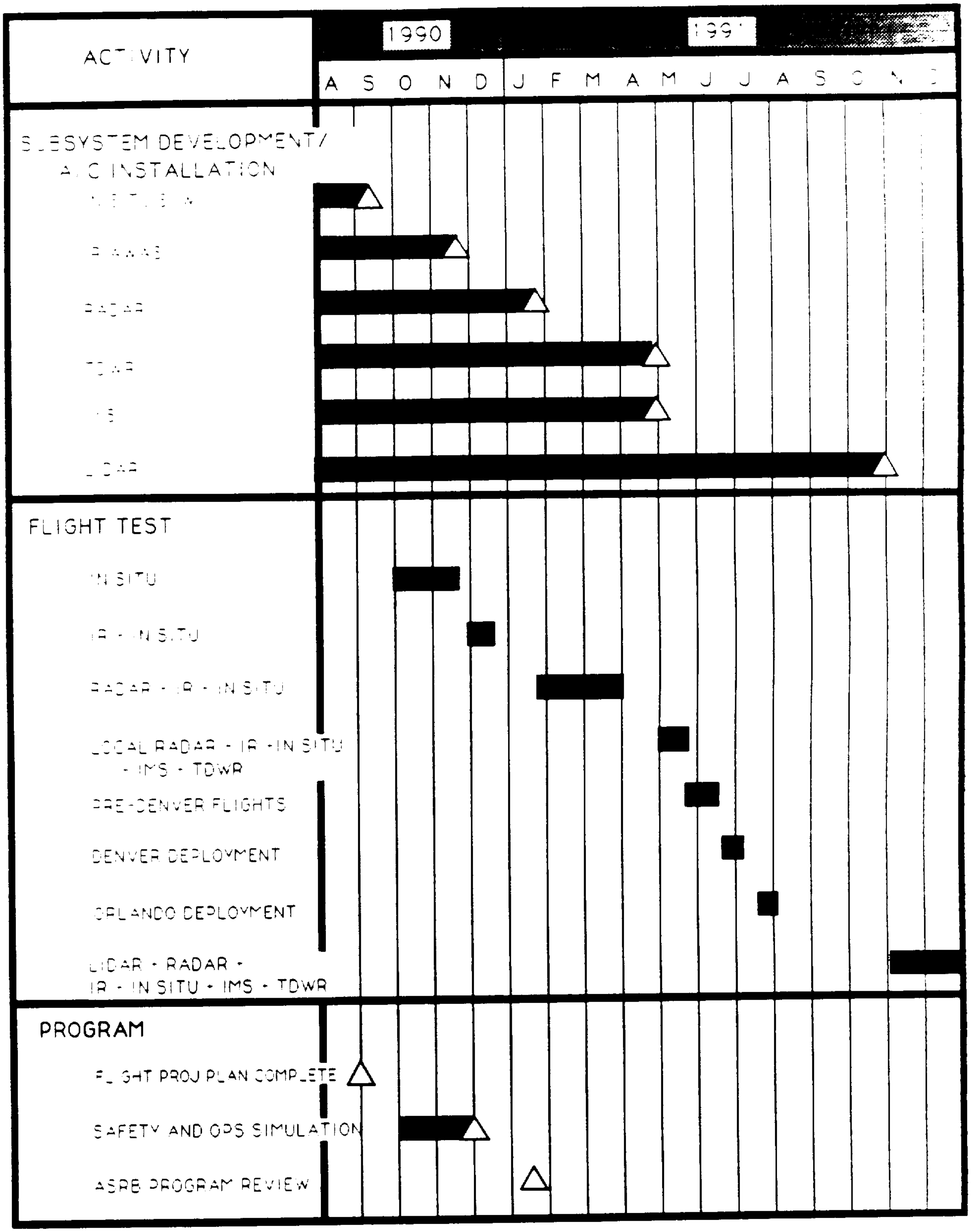
UNSAFE WINDSHEAR EXPOSURE

FULL LANDING CONFIGURATION, APPROACH SPEED, DESCENDING ON GLIDESLOPE, LOW ALTITUDE, DELAYS IN RECOGNIZING SITUATION

NASA 515 FLIGHT TESTS

CLEAN A/C CONFIGURATION, SUBSTANTIAL EXCESS SPEED, LEVEL FLIGHT, HIGH ALTITUDE, WRITTEN PLAN, FULLY BRIEFED, ANTICIPATING EVENT LOCATION SIZE, AND SEVERITY, IMMEDIATE RECOGNITION OF CONDITIONS, EXIT PROCEDURES KNOWN IN ADVANCE

WINDSHEAR 1990 - 1991 FLIGHT PROJECT SCHEDULE



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NASA Langley Flight Test Program - Questions and Answers

Q: WALT OVEREND (Delta Airlines) - How do you judge go, no go decisions on the airplane before you penetrate a microburst? What parameters are you working from?

A: MIKE LEWIS (NASA Langley) - We establish a reflectivity limit over which we won't go through and we'll use the standard weather radar for that function. There will be a fairly rough reflectivity limit corresponding to the red level on the standard radar which is about 40 to 50 dBZ. For lightning avoidance, in general we're not going to stay away from all lightning but certainly areas of severe lighting activity we will avoid. For that we will use a lighting detector storm scope to be installed on the aircraft. We will be operating at locations covered by TDWR and will be relying on up linked TDWR information to determine whether or not the microburst strength is over the penetration threshold. We will also use their support for hail detection and avoidance in addition to the standard weather radar for that function. Additionally, we will have a number of wind shear sensors on the aircraft and to the degree that we have some operational confidence in those sensors we'll also use those, albeit research pieces of equipment for determining the limits over which we won't fly through. Lastly, there is pilot's discretion, everything is up to the guy in the front flying the airplane and anything that he's not comfortable flying through, for whatever reason, the airplane won't go through.

Q: UNKNOWN - In regard to a lot of the accidents we've seen, the encounters are down around 500 to 300 feet, as you go on with your test program are you planning on trying to gather data down there, especially for the radar sensors?

A: MIKE LEWIS (NASA Langley) - Yes. The information I presented as to what our final altitude limit will be was preliminary. That's still to be determined. We will be determining that form the piloted simulations through the microburst models which will show what kind of safety margins we have. However, I think as a general philosophy, we don't need to be operating exactly on approach in the same configuration that a real encounter would be. For test purposes, all we need to do is verify the function of the experimental systems that we have on board. So we want to fly low enough to get a healthy enough horizontal component of the shear but not necessarily put ourselves in a situation where we're flying through the maximum of that horizontal component down at the 200, 300 foot level. So as long as we stay within a band that has enough of the horizontal exposure and not totally a vertical component of the microburst we believe that we can evaluate the function of these various instruments.

ROLAND BOWLES (NASA Langley) - We've taken great pains in both of the pulse Doppler systems to provide pointing capability. When we are at 1500, in that vicinity, our problem is to keep range gates out of the ground. We are probing all the way down. The idea is to manage the antenna tilt in such a way as to not process range gates that are intersecting the ground and picking up clutter, both moving and fixed. The point is the remote sensors will be able to probe down. We can point the sensors, and we can slew the sensors. It's not necessarily confined to looking in a very narrow cone in front of the airplane.

UNKNOWN - I understand the safety constraints on that from the flight test standpoint. I guess your answer leads to more questions. You say you're already running into range problems of picking up ground clutter which are obviously going to get worse the closer along the approach or lower altitude you're at.

ROLAND BOWLES (NASA Langley) - That's the key research question we are dealing with, the whole emphasis in the radar develop program. The key thing is managing antenna tilt in such a way that along with clutter suppression techniques at the signal processing we can detect the wind shear, while de-emphasizing the contaminating effects of ground clutter. That's the research question. If we can't solve that problem then radar is not a suitable solution. We think we can by managing antenna tilt as a function of altitude, always keeping the 3 db point of the antenna out of the ground. The trade off is, we don't want to do that in such a way as to overlook the top of the outflow and therefore underestimate the threat. That's the trade off. And the best way we get the answer to those questions is to configure the system, fly and evaluate.

Q: UNKNOWN - Isn't there an obvious advantage to a ground based LLWAS type approach over the airborne equipment in avoiding the look down clutter problem?

ROLAND BOWLES (NASA Langley) - I would think so because they're on the ground. You're at least looking up a bit with your narrow beam antenna. These guys have spent considerable effort, time, resource, money and agony, no doubt, in solving the clutter return question. It's not a question of ground versus air. The policy has been set. There shall be 47 radars deployed at major TCAs and there is an airborne equipment rule. The point is, what is the airborne equipment technology that best does the job for the least amount of bucks and makes incremental improvements in safety. I don't know what the answer to that question is but we think we'll have more information to draw inference on it after we finish our flight program with these three sensors.

UNKNOWN - Again, 750 feet seems a bit high. I'm still concerned about the issue of where the down flow becomes outflow and to the extent that you are almost at that transition altitude and that you are looking at pilot technique above and beyond the sensors, or the pilot's ability to interface with the information in the flight deck. That's been an area of difficulty, as you know for us, in the development of the wind shear training aid and pilot technique and so forth, to recognize the safety concerns. But it does seem there is area below 750 feet that needs exploration.

ROLAND BOWLES (NASA Langley) - In the NASA program we're not looking at pilot technique. We're using the airplane as a platform to hold the sensors. We're not looking at recovery techniques or anything like that. Based on the totality of data obtained over the many years of the test program the maximum outflow is, statistically, somewhere between 80 and 150 meters altitude and the half velocity point is 300 to 400 meters typically. So there is plenty of signal and outflow aloft based on, I would think now, hundreds of measurements of microburst.

MIKE LEWIS (NASA Langley) - The preliminary limits that I was showing are only applied when we've got a microburst out there that's over our threshold limit, the threshold being around 0.1 or so. We will then impose a minimum altitude constraint. Below that threshold we'll fly all the way down to touchdown. These sensors will be operational in the research mode all the way down through touchdown even through microburst or whatever other weather phenomena below the 0.1 level threshold. So there is still the opportunity to detect and evaluate the sensor's performance all the way down to touchdown within the flight test program.

BILL MELVIN (Airline Pilots Association) - I've got to speak to this maximum outflow issue. This was an idea that was used to perpetuate the ground cushion theory myth of microburst or downdrafts. That myth was that in a downdraft you didn't have to worry about flying under it because it couldn't blow through the ground so there had to be a cushion down there. So, over the years people developed this idea that the maximum out flow occurred somewhere around 300 feet, it's also called 100 meters. With that kind of philosophy it means that it gets better below 300 feet. Therefore, the only reason the airplane would hit the ground was that the pilot didn't fly it right. Albert Bedard and S. J. Caplan have measured the maximum outflow, it's in AIAA paper, 87-0440, and they found that in the highest velocity downdrafts the maximum outflows occurred at about 10 meters, roughly 30 feet above the ground.

ROLAND BOWLES (NASA Langley) - I agree with you Bill. I don't know exactly where it is, but I know one thing, its got to got to go to 0 somewhere down there. It's just a question of how thick the boundary layer is.

Session V. TDWR Data Link / Display