N87-25276

B-57B GUST GRADIENT PROGRAM

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INTRODUCTION

The NASA B-57B Gust Gradient Program (GGP), is a NASA multi-center program involving Ames Research Center and its Dryden Flight Research Facility; Langley Research Center; and Marshall Space Flight Center. The program objectives, along with photographs of the aircraft and other information on the effort, are given in Figure 1. As indicated in the figure, the primary objective of the program is to get wind gust data which can be used in new design criteria for aeronautical systems. The GGP data could also be used to provide turbulence information for use in simulation programs.

The need for new design criteria is readily seen if one considers this wind gust assumption; namely, that the wind varies only in the longitudinal direction (Figure 2). However, the left side of the figure illustrates the wind variation in a more realistic manner; that is, that the wind varies in the lateral, longitudinal and the vertical directions, as well as in time.

Indicated in Table I is the quantity of GGP data that has been collected to date, suggestions relative to enhancing and augmenting the facility, and tentative plans for additional data collection. Table II shows the distribution of the data with regard to location, degree of turbulence, and whether in rain or not. This information was ascertained from the flight engineer's notes for each of the flight tests. Of the data listed in Table I, only a small amount has been analyzed. The data analyzed so far consist of three sets of data from the flight tests in conjunction with JAWS, and two sets from the flight tests at NASA Marshall Space Flight Center (NASA/MSFC). None of the other data have been reviewed at this time. However, it is planned that all of the data will be analyzed in detail in the near future.

The data chosen for analysis, JAWS and NASA/MSFC, were selected for specific reasons. Namely, the JAWS cases were chosen because of the desire to investigate low-level turbulence (below 1,500 feet) associated with wind shear. Thus, the three JAWS data sets selected had severe turbulence, and also encompassed takeoff, level flight, and approach data. An example of this data is given in Figure 3. In this figure, U is longitudinal, V is lateral, and W is the vertical component of the wind as measured at the nose boom of the B-57B. The bottom three plots are the wind speed differences between the wing tip booms. The data were differenced in order to see the small-scale spatial variations in the wind and to remove the mean wind motions. It is easy to see the short-period variation in the wind as measured by the nose boom wind sensor. For example, inspection of the lateral wind speed time history in Figure 3 shows an approximate 70 kts difference in the lateral (V) component between 100 and 125 seconds. Also easily seen are the wind gradients (difference between wing tip sensors), e.g., the variation in differences appears to be about ± 10 kts for the longitudinal and lateral, and a little more for the vertical. A presentation of the turbulence aspects of these data is given in reference 1.

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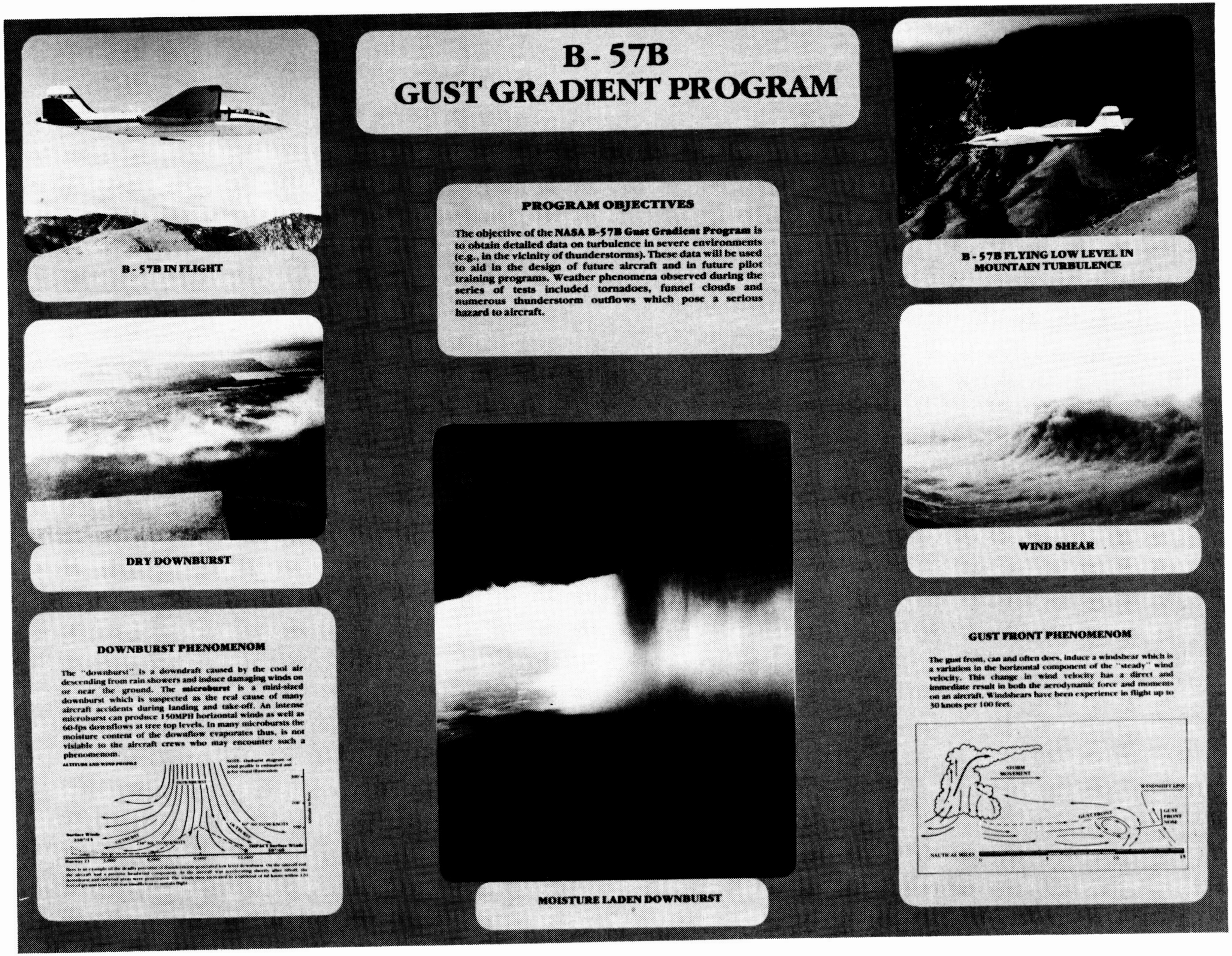

Figure 1. B-57B Gust Gradient Program.

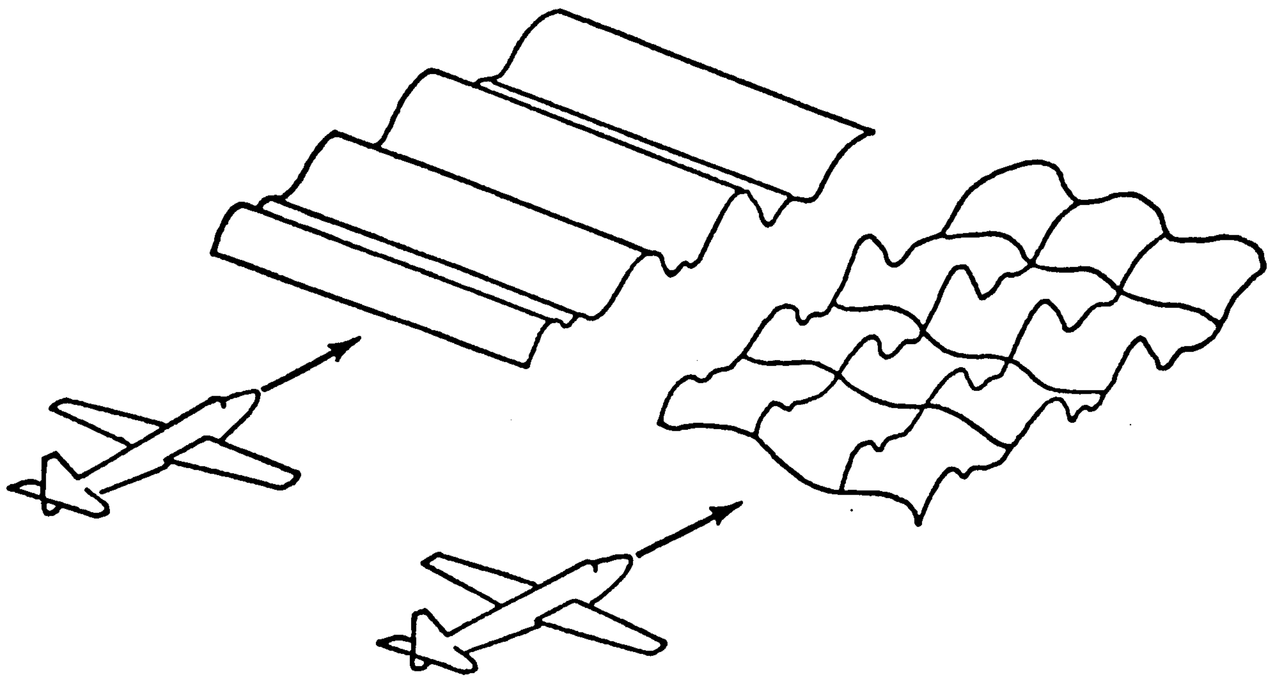

Figure 2. Assumption of Turbulence Models.

Table I. Program Status

- Status of Data Sets
  - 11 Joint JAWS, Denver
  - 3 NASA/Dryden, Edwards
  - 3 NASA/MSFC, Huntsville
  - 5 NSSL, Oklahoma City
  - 2 NASA/Dryden, Edwards
  - 7 Joint NASA/NOAA, Boulder
- Data Enhancement and Augmentation
  - Statistically significant data samples for approach and takeoff (similar to MSFC field test)
  - All weather capability for data gathering in wet environment and closer to storm centers
  - Small-scale wind and turbulence structure by flying paths in direct comparison with other instrumentation; i.e., Doppler radar, Doppler lidar, airborne lidar (Convair 990)
  - Data to supplement numerical forecasting models
- Tentative Plans
  - Participate in NSSL's 1985 Spring Storm Program
    - Low-level gust gradient data for a wet environment
    - Gust front as contrasted to microburst
    - Flights directly down radar beam
  - Joint effort with C-990 Airborne Lidar Field Program (winter '84-'85; Lone Pine, California)
    - Turbulence
      - Large scale -- lidar
      - Small scale -- B-57B
    - Altitude --2000 - 45,000 ft AGL
    - Data uses (B-57B):
      - Augment present gust gradient data
      - Verification of UDRI turbulence index relative to CAT location
      - Mountain waves (AGW) basic studies

Table II. Type of Data

Site	C	C_R	L	L_R	L-M	$(L-M)_R$	M	M_R	M-S	$(M-S)_R$	S	S_R
TAKE-OFF												
Denver (JAWS)	18	0	9	1	1	0	4	0	1	0	0	0
DFRF	10	0	3	0	3	0	0	0	0	0	0	0
MSFC	2	0	0	0	0	0	0	0	0	0	0	0
OKC	0	0	8	1	0	0	0	0	0	0	0	0
Boulder	8	0	8	0	0	0	1	0	0	0	0	0
TOTAL	38	0	28	2	4	0	5	0	1	0	0	0
LEVEL FLIGHT												
Denver (JAWS)	29	4	70	26	24	5	33	9	9	2	2	0
DFRF	8	0	20	0	10	0	20	0	1	0	14	0
MSFC*	24	0	0	0	0	0	0	0	0	0	0	0
OKC	21	4	13	11	2	1	0	1	0	0	0	0
Boulder	68	0	42	0	0	0	2	0	0	0	0	0
TOTAL	150	8	145	37	36	6	55	10	10	2	16	0
LANDING												
Denver (JAWS)	19	0	7	2	1	0	4	0	1	0	0	0
DFRF	5	0	3	0	3	0	0	0	0	0	0	0
MSFC	10	0	0	0	0	0	0	0	0	0	0	0
OKC	5	0	7	3	2	0	0	0	0	0	0	0
Boulder	11	0	12	0	0	0	0	0	0	0	0	0
TOTAL	50	0	29	5	6	0	4	0	1	0	0	0

Nomenclature:
- C - Calm or no indication
- L - light turbulence
- L-M - light to moderate turbulence
- M - moderate turbulence
- M-S - moderate to severe turbulence
- S - severe turbulence
- Sub R - indicates rain conditions

*5 tests flown in circles around MSFC's lidar.

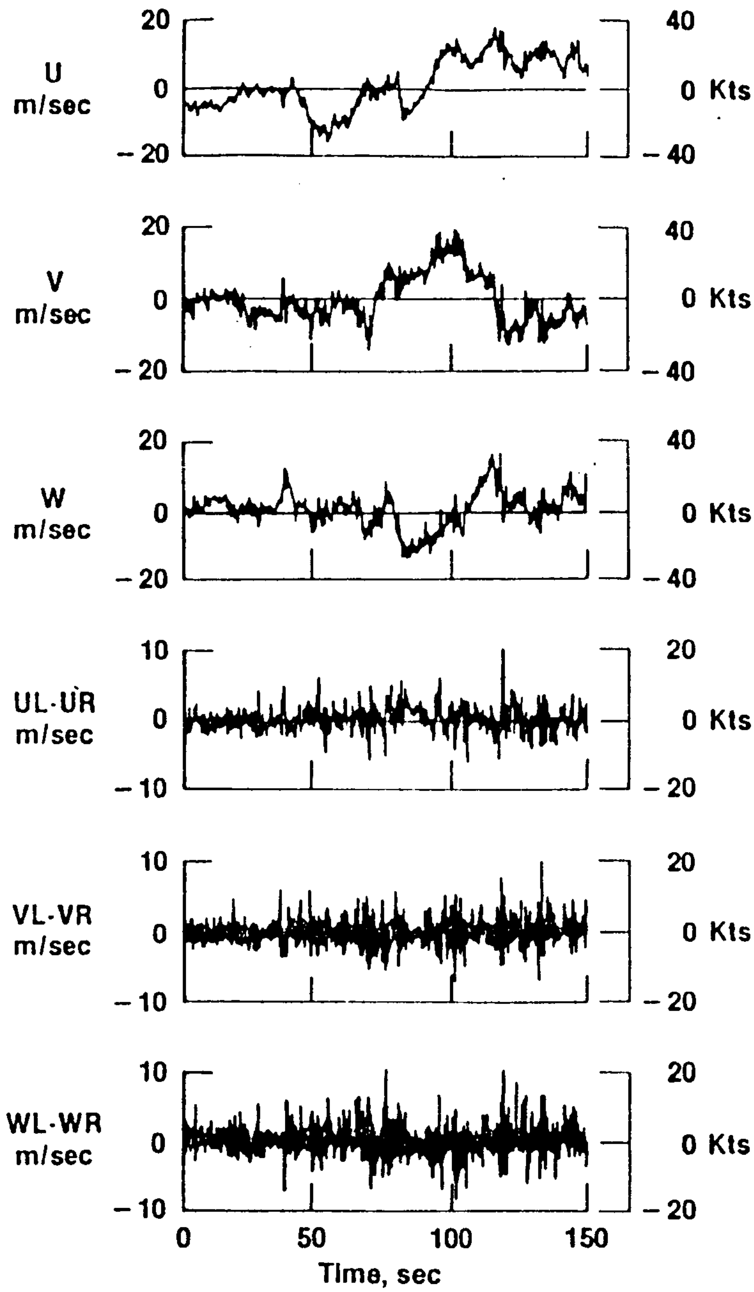

Figure 3. Plot of Gust Gradient Data from Flight 7, Run 10 on July 15, 1982, in the Denver, Colorado, area.

The data from NASA/MSFC was selected in order to do a comparative analysis of aircraft-measured data with Doppler lidar-measured data and also with data from a five-tower array at the MSFC. In collecting these data, the aircraft was flown on a 3° glide slope toward the lidar, while the lidar was sampling data along the same slope. The comparison of the aircraft and lidar data was very good. In fact, the quality of the comparison was such that additional data were desired and were collected at the Boulder, Colorado, tests using the NOAA lidar. The data comparing the aircraft-measured winds to tower-measured winds will be used to investigate the "frozen turbulence" theory of Taylor.

Figure 4 shows four frames from a film* which illustrates the wind variations over the airfoil of an aircraft. The film is an animation which illustrates the rolling and yawing of the aircraft as a result of the wind. For the purpose of the animation, roll and yaw were exaggerated by a factor of five, so that aircraft response to the encountered turbulence is easier to observe. The arrows represent the wind vectors. Changes in arrow length correspond to changes in speed, and the arrows point in the direction of the wind. The data for the movie was from a level flight (2,000 feet AGL) made at the JAWS on July 15, 1982. The aircraft was flying with an indicated airspeed of about 200 kts.

REFERENCE

1. Frost, Walter: Turbulence models. Wind Shear/Turbulence Inputs to Flight Simulation and Systems Certification, NASA CP-2474, 1987, pp. 125-149.

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* A copy of this film can be made available through ED42, NASA Marshall Space Flight Center, Marshall Space Flight Center, AL 35812.

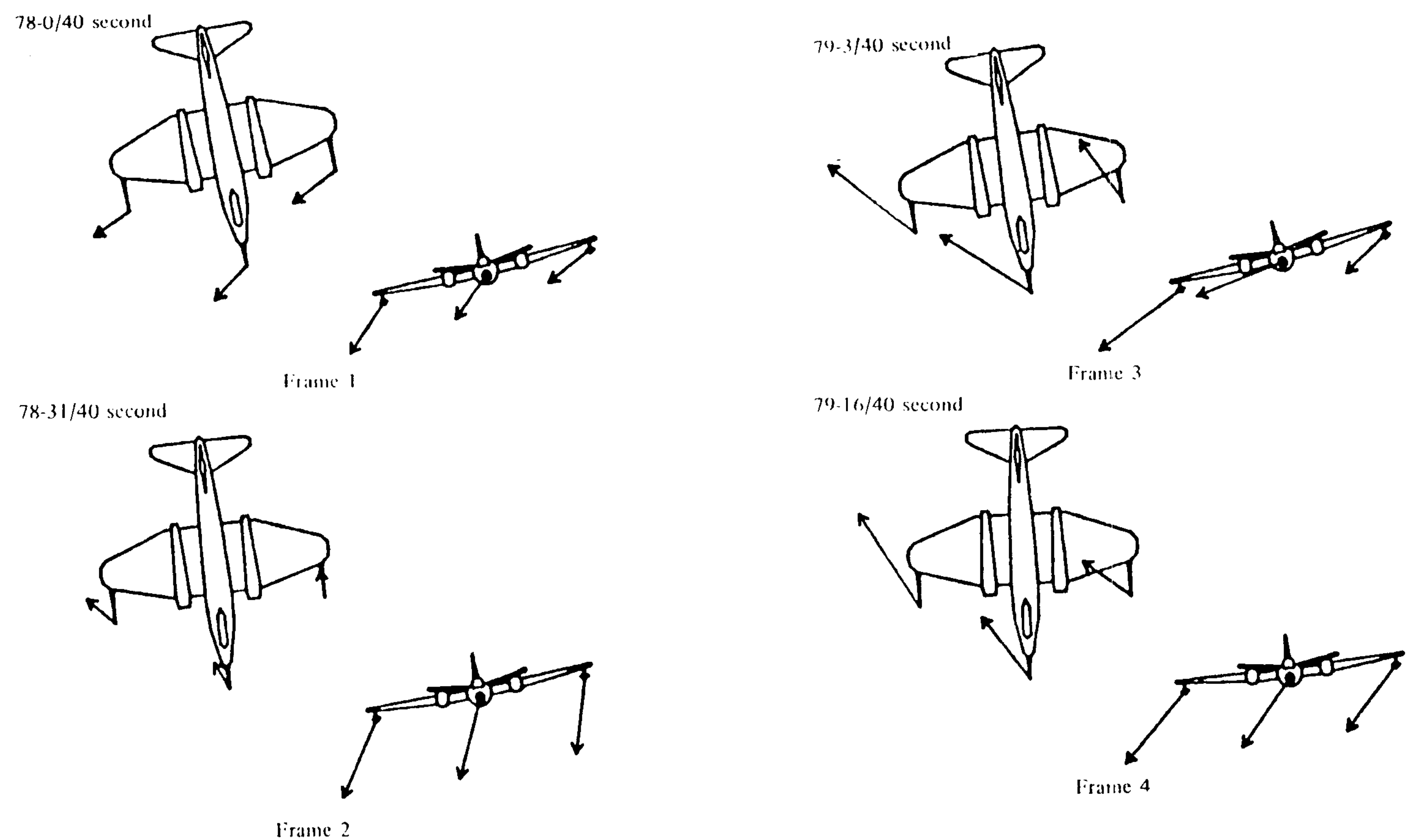

Figure 4. Illustration of Wind Velocities During the 78 Second of the Data Record.